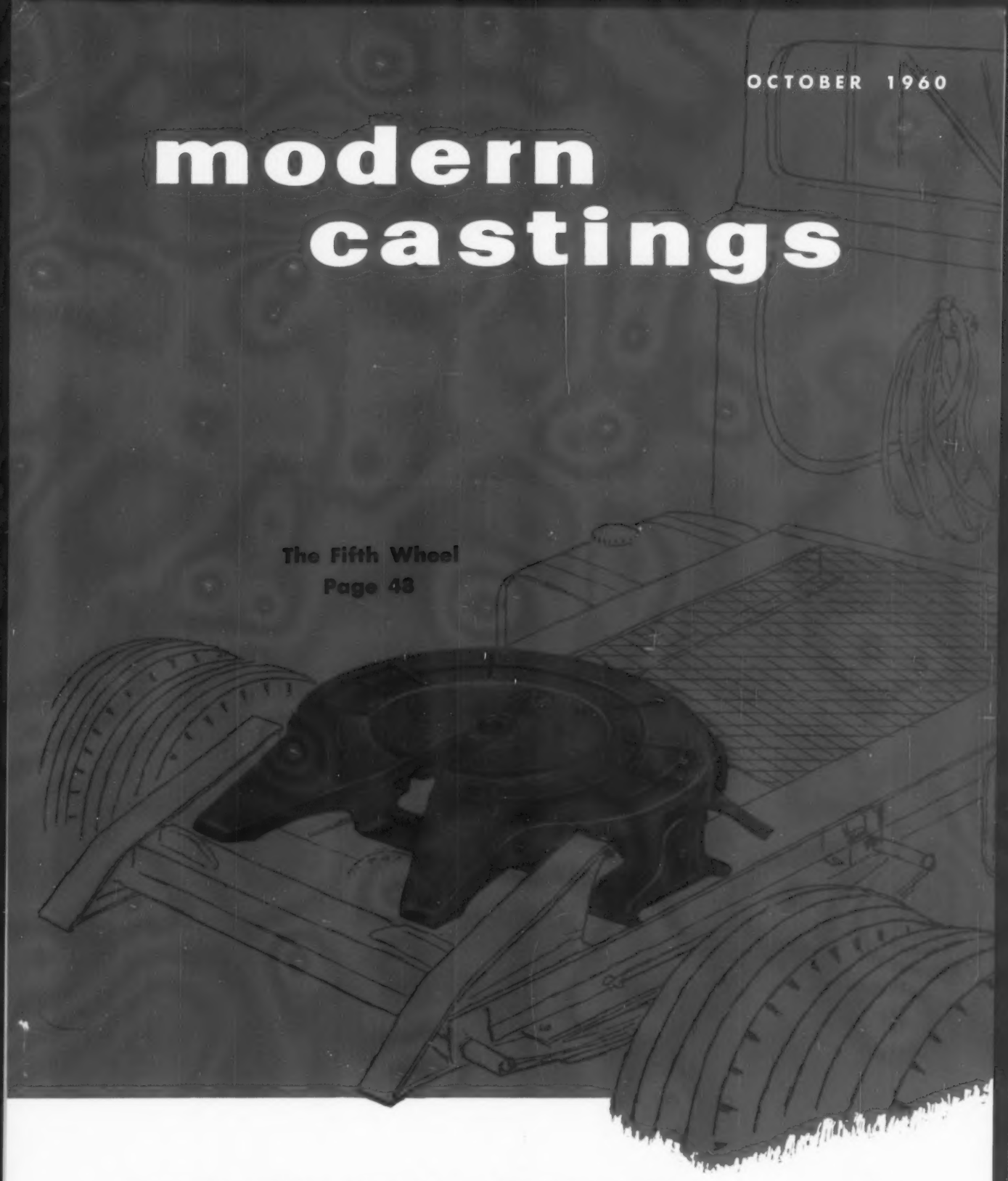
OCTOBER 1960

modern castings



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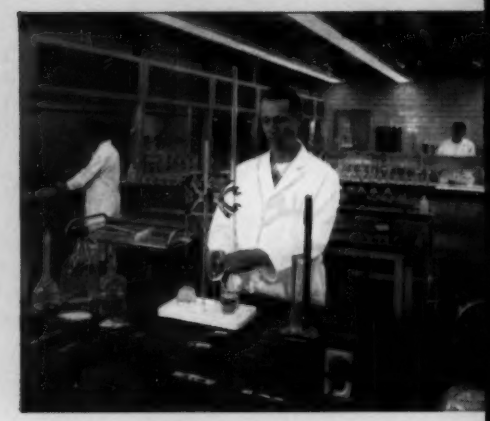

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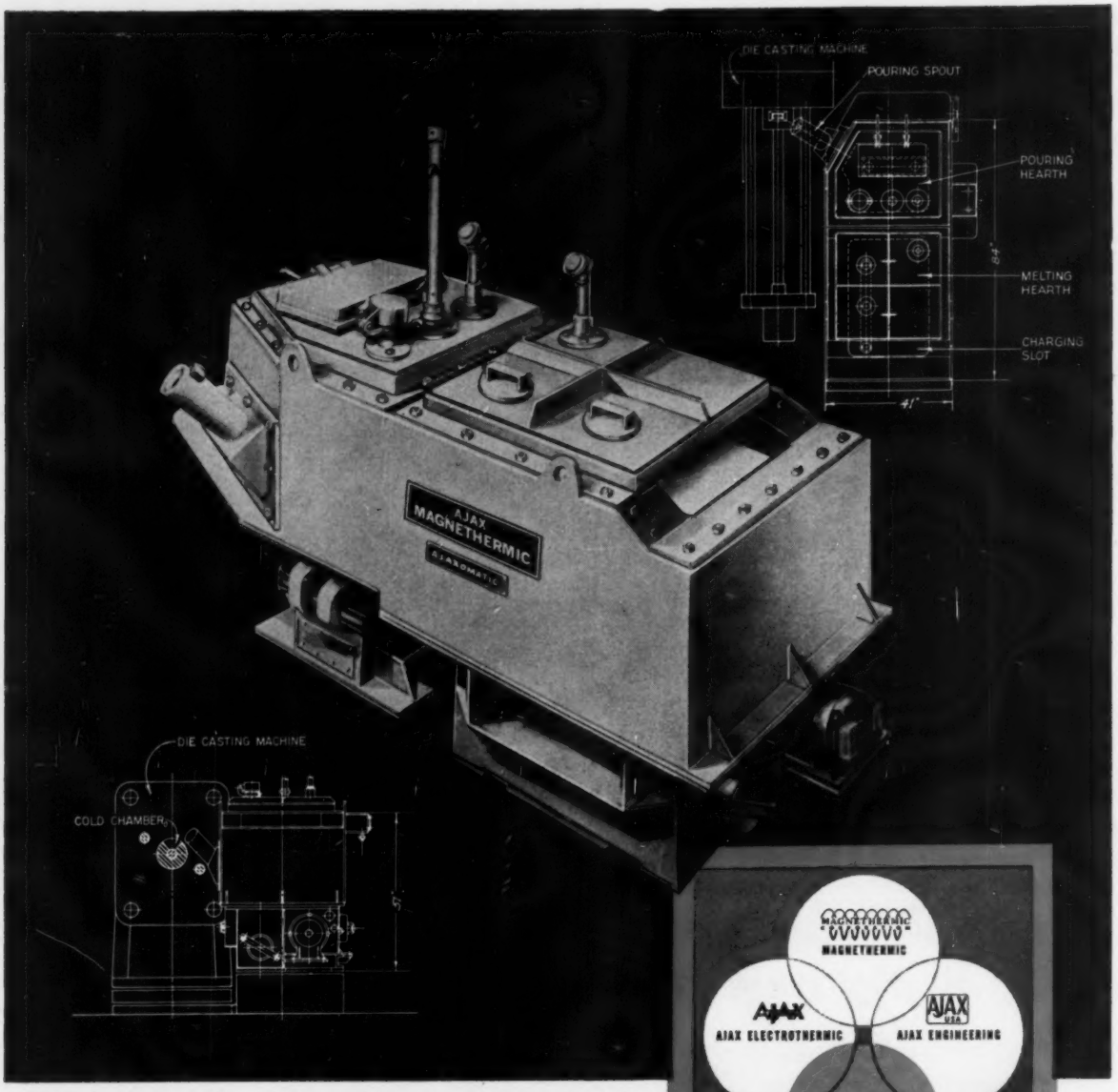

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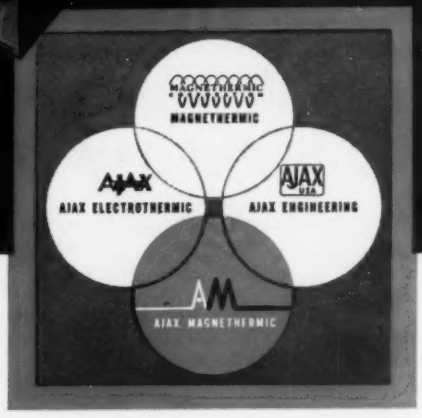

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October 1960 Vol. 38, No. 4

modern castings

world-wide technical authority of the metalcasting industry

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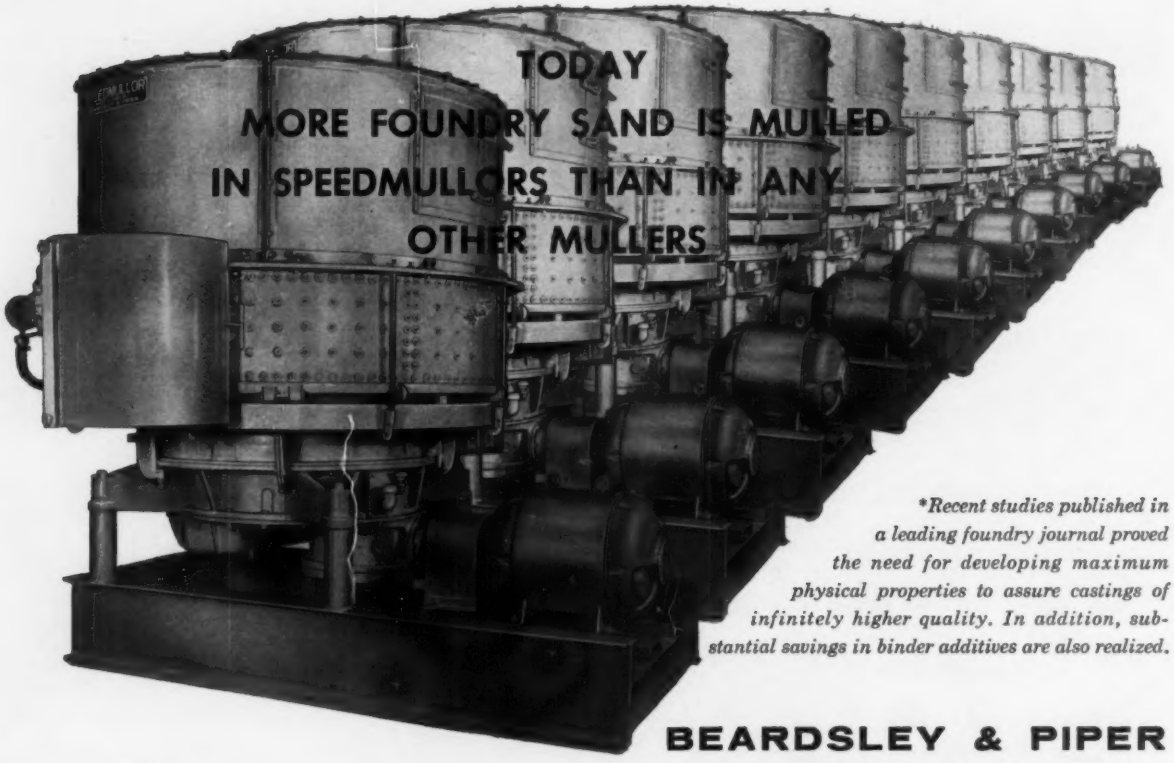

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Let's look at...

A NEW CHALLENGE!

FOUNDRYMEN TODAY are either on the threshold of great advancement—and lush profits—or they are blindly facing the tortuous decline of a great industry. I'll take the first view!

Steel mill activity is no longer as important a business barometer as it used to be. The wants of consumers and manufacturers are changing—and the effects on old-style products and processes are tremendous. Steel mills are being hurt. *But this does not mean the foundry industry is going downhill.*

A great technological explosion is taking place—caused by new developments in countless plants and laboratories of foundries all over the world. New processes and new uses are being discovered and exploited almost daily. Uses for metals are changing. Here is where foundrymen must adjust.

There are bright vistas for those who have the courage to try the new—and who obtain the latest know-how essential for success. Marketing one's products, a relatively new word in many foundry sales departments, is now a key factor, once products and processes are developed.

Every month you can find clues to new products and processes in our MODERN CASTINGS marketing opportunities series. You get the guidance and advice of national and international technological and management experts.

For instance, in this issue you can read about the significance of "The Fifth Wheel," and what it means to the foundry industry. On page 45 is a special report which points out additional opportunities for foundry products in the trucking industry.

This is our way of demonstrating to you that the foundry industry has the leadership and the technical knowledge to gain *new growth* and *new markets.*

MODERN CASTINGS is helping every month with its *exclusive* editorial content—both trend and technological information. But this is not enough. We can, as interpreters of trends, and reporters of technological breakthroughs, alert and guide you. But each one of you must make the most of these opportunities, even though it means altering traditional ways of doing business.

It's a team effort today. We're glad to help all we can!

Harold E. Green

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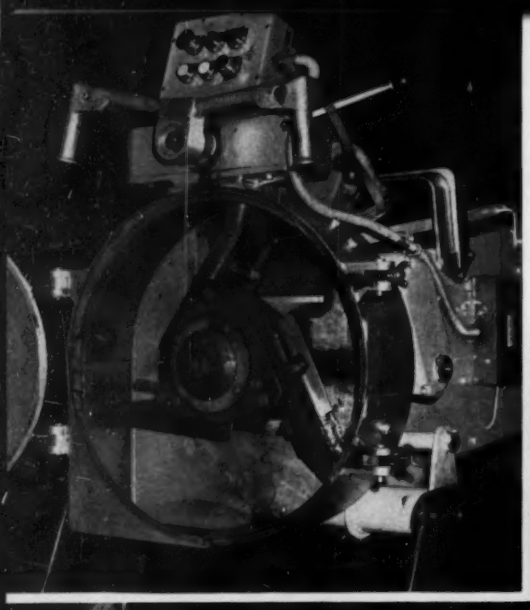

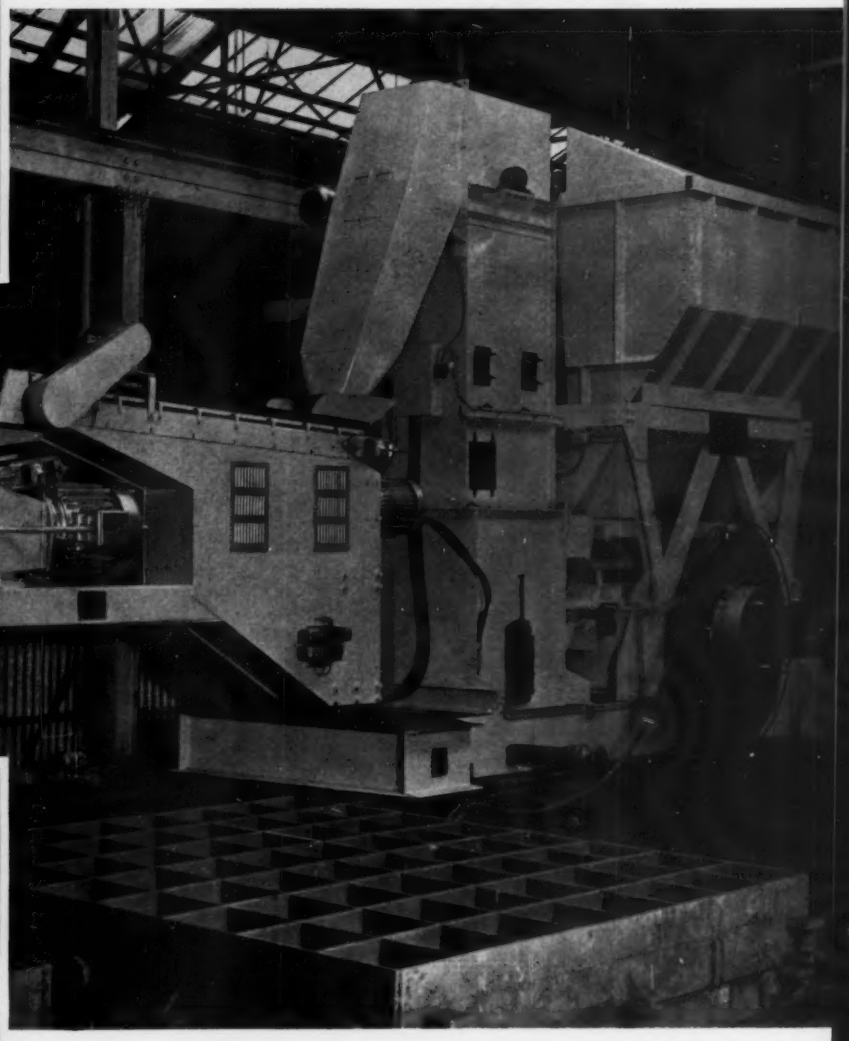

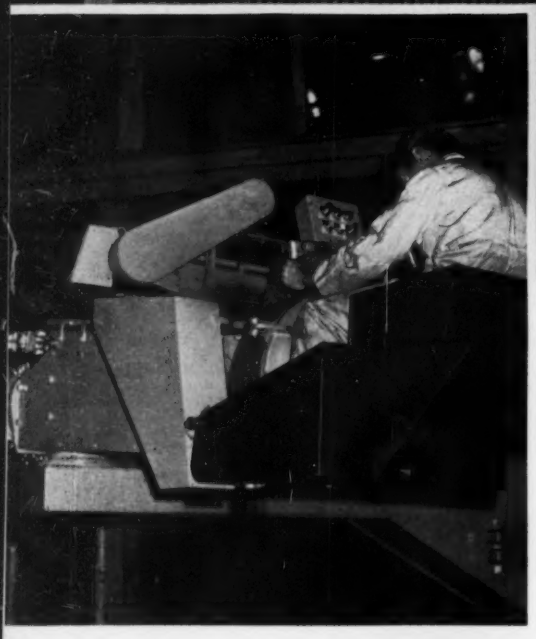

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Around the World with Modern Castings

UNITED STATES

What to do with the huge stock of depleted uranium? It's currently accumulating at the phenomenal rate of tens of millions of pounds a year. Researchers at Battelle Memorial Institute find promising possibilities for depleted uranium to be used as a spheroidizing agent in nodular iron, a scavenger for impurities in steel and other metals, and as a dispersion hardening agent. Once again we witness serendipity contributing an unexpected benefit to the metalcasting industry.

CZECHOSLOVAKIA

From behind the Iron Curtain we learn that steel foundries are vitally concerned with finding refractories that will resist the severe high temperature erosive forces of molten steel. Czech foundrymen may have come up with an answer to this world-wide problem in the form of a new molding mix—96% CrMg and 4% sulphite liquor. Clean casting surfaces and good core collapsibility are being claimed for the concoction.

JAPAN

The Research Institute for Iron, Steel and Other Metals of Tohoku University announces development of Sendite—a graphitic steel casting alloy containing more than 1 per cent carbon. The graphite is spheroidal in as-cast condition. Castability of the alloy is said to be excellent, possesses high strength and good wear resistance.

ENGLAND

Magnesium castings will be more competitive with aluminum than ever as result of research just disclosed in England. Particularly promising is the alloy -2.54% silver, 2.74% neodymium, 0.6% zirconium, balance magnesium. Proof stresses as high as 13 tons per square inch are not unusual. When proof stresses are divided by the alloy's density, values exceed anything achievable in other magnesium and aluminum base alloys. Designers should find many applications which put this advantage to practical use.

FRANCE

The Renault Works have successfully developed the new hot core box method for producing more accurate cores at lower cost. Sand bonding comes from a sugar-based binder containing a catalyst to accelerate polymerization. Aluminum alloy core boxes are heated to 390-445 F. and filled with sand mix by ramming or blowing. The sugar derivatives polymerize instantly when they reach 320-340 F. Within several minutes the outer shell of sand hardens leaving the center uncured. Core is removed from box by ejector pins. Renault makes cores for water jackets, distributors, and differential cases. The process also lends itself to making stack molds for rocker arms and other alloy iron and steel parts. The hot core box process has the advantages of cheap binder, simple mixing, high accuracy, and elimination of driers, core wires, and drying ovens.

Around the World . . .

RUSSIA

Just released is a report which reveals a two-layer shell molding process saving Russian foundries at least 12 per cent on resin and labor costs. Hot pattern plate is first coated with a thin layer of fine grained sand bonded with 5 per cent resin. This shell is painted with sodium silicate (waterglass) and then backed up with a layer of coarse waterglass bonded sand. This backup layer can be contoured to the shape of pattern or struck off level with a frame enclosure. Back-up layer is gassed with CO_2. Mold halves are held together by clamps or weights (no glue or cement). Results show the mold to have good rigidity for producing accurate castings and highly permeable for carrying away gas. Size limitations are extended to the 220-440 pound range. Process is particularly attractive for large ferrous castings.

ENGLAND

Watch out for even the slightest trace of lead in your gray iron castings! Small amounts of lead—over 0.003 per cent—in gray iron castings can seriously reduce its strength and may lead to premature failure. Loss of strength is attributed to formation of spiky and Widmanstatten graphite. Inspect your scrap metal charges closely. Leaded steel, bearing metals, vitreous-enameled metal are only several of the possible sources of harmful lead.

UNITED STATES

At New York University, H. W. McQuaid, consultant, opened new vistas for ductile iron as a material suited to hot working. By careful heating up to 1900-1950 F., ductile iron is amenable to shaping by forging, extruding, coining, and pressing. After annealing at 1700 F. and slow cooling, excellent combinations of strength and ductility can be achieved. Foundrymen may recognize applications where casting followed by hot working will meet new customer needs.

HOLLAND

High-speed automated core shooting and CO_2 gassing with turntable equipment is the answer to fast core production, according to a large Dutch brass foundry. Cores are used in permanent mold casting of water and sanitary fittings. Three different core boxes can be mounted on the turntable. One station shoots the core, next station gases it, and third station ejects. European foundries seem to be making more extensive use of CO_2 cores for applications requiring mass production than is generally true in the United States. Perhaps new high-speed automated production equipment will be a key to future growth of this process.

Circle No. 151, Page 161

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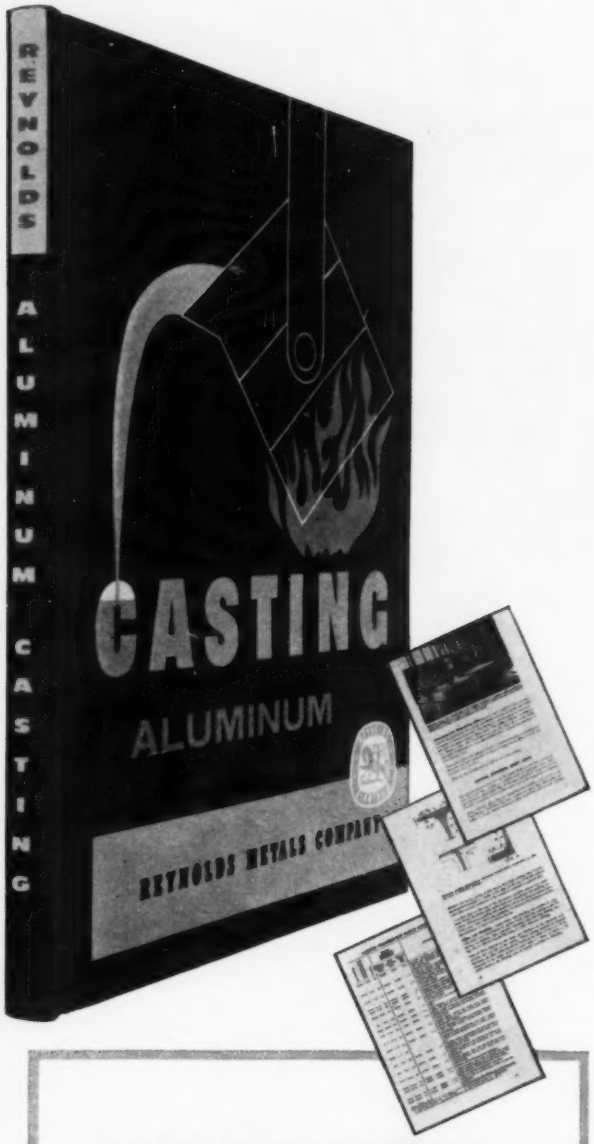

Casting Aluminum is a highly informative manual published by the Reynolds Metals Company. It's available—free—to everyone concerned with casting. Hard cloth-cover bound, and profusely illustrated with photographs and diagrams, *Casting Aluminum* is a valuable asset to every technical library.

Get fast delivery on aluminum pig and ingot . . . contact your local Reynolds sales office for the name of the Reynolds Pig and Ingot Distributor in your area.

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REYNOLDS ALUMINUM

Watch Reynolds new TV show "Harrigan & Son", Fridays; also "All Star Golf", Saturdays—ABC-TV.

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Alloy Classifications
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Heat Treatment
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Reader Opinions and Ideas . . .

GRAY IRON OPPORTUNITIES

I have enjoyed reading "15 Ways Your Gray Iron Business Can Grow," in the July issue of MODERN CASTINGS.

The future of the gray iron (and for that matter of the whole) foundry industry lies in intelligent design to use the best characteristics of the particular metal involved, and then aggressive selling to put these ideas across. One is of no use without the other.

Costs must, of course, be kept in line or decreased since there is obviously no point in saving money by good design and then throwing it away by lack of control over ordinary manufacturing costs. The cost of molten metal is a major item in the iron foundry industry, and especially in mechanized shops where it will likely grow in proportion.

There is a real answer to this in using liquid iron direct from a small smelter, provided a tonnage of about 150 tons per day or more is involved and reasonably close raw materials are available.

I saw a foundry in Europe with a small electric smelter making iron from ore which had only 27 per cent iron, and using the product directly in the foundry, at lower cost than standard methods using scrap and pig.

We ourselves have made a detailed study of this matter and show a return on investment of over 35 per cent. The principal stumbling block, especially in the smaller sizes of smelter, is the relatively high capital cost. This cost is low compared to a blast furnace, but high compared to a hot-blast cupola installation.

J. E. REHDER
Canada Iron Foundries, Ltd.
Montreal, Canada

ALUMINUM EXPORT STATUS

In the "Around the World" section of your August issue, you carry a paragraph on scrap aluminum imports. I should like to comment on two points which are not quite factual, as they should be, to give your readers a clear understanding of a problem of direct interest to them. These are:

1) Your inference that Aluminum Smelters Research Institute requested the Department of Commerce to "monitor" exports;

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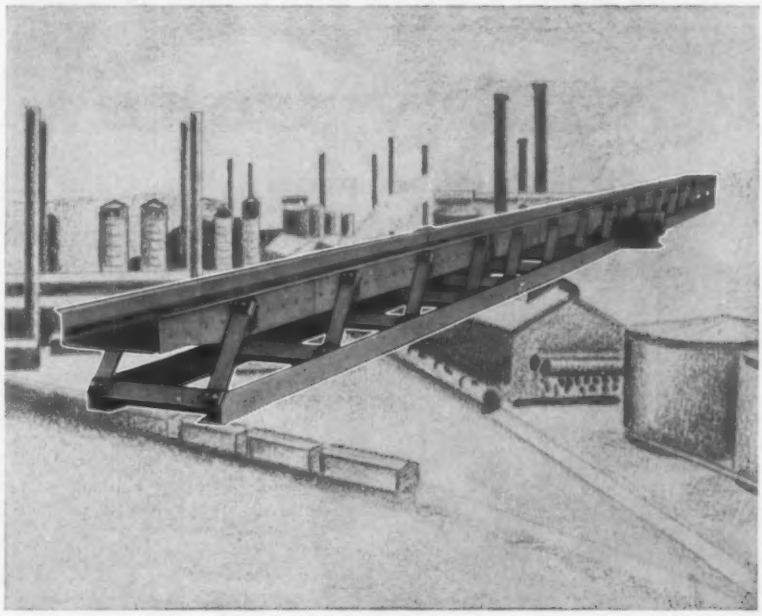

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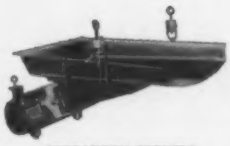

VIBRATORY FEEDERS
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Reader Opinions . .

Continued from page 11

2) You ascribe to the National Association of Secondary Material Industries, Inc., a claim which has been advanced by but a single division of that group—the Metal Dealers Division.

Regarding the question of "monitoring" exports, it should be made clear that A.S.R.I. has never asked the Department of Commerce to monitor the flow of aluminum scrap in export. However, we have repeatedly asked over the past year that the department proceed under the Export Control Act to curtail and control exports of aluminum scrap, since they now constitute a serious drain of strategic materials. This poses a threat to domestic industry—the foundries and smelters.

Each request has been met by the department with a denial, and the statement that they "are watching closely." The department itself therefore instituted the "watching" or "monitoring" and it is very disturbing to us to note that the more they watch or monitor, the greater the volume of exports.

As to the other item, you stated that "The National Association of Secondary Material Industries, Inc., claims there is a surplus of domestic aluminum scrap." I must again point out that, in the interest of accuracy, this claim should be attributed to the Metal Dealers Division of N.A.S.M.I.

Such a claim implies a large backing-up, in dealers hands, of unmovable aluminum scrap available for immediate loading and shipping. That is clearly not the case, in the nonferrous categories, as indicated in an article in the July 13 *American Metal Market*.

Under the heading, "Boston Scrap Markets at a Standstill as Intake Dwindles," the report states: "The dealer buying level is sustained by the need to get covered against orders . . . In the case of aluminum, though now inquiry is said to be less, the coverage needed to insure tonnage for export commitments over the next two months is holding dealer bids to 13.00¢ for old cast and sheet, and 15.00¢ top for mixed clippings."

If the foundry industry understands the facts, it will quickly realize that our attempts to stem the raging flood of exports of aluminum scrap are efforts to protect them and ourselves, in our mutual need to remain competitive with the "hot metal" deals and other more transient "gimmicks."

In closing I should like to congrat-

Continued on page 16

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The Choice is Wide, The Value is High with Hevi-Duty Furnaces

Here are three users of melting and holding furnaces. They represent three methods of casting, using either fuel-firing or electric resistance heating, yet each has found the answer to his needs at Hevi-Duty. This is not surprising.

Hevi-Duty now offers the widest choice of heat processing furnaces — both electric and fuel — in the industry. This is important in terms of furnace value. It means you can probably find a proven unit that fits your needs exactly.

Why not consult a Hevi-Duty Sales Engineer soon? Let him show you why a wide choice means a high value in furnace equipment.

HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

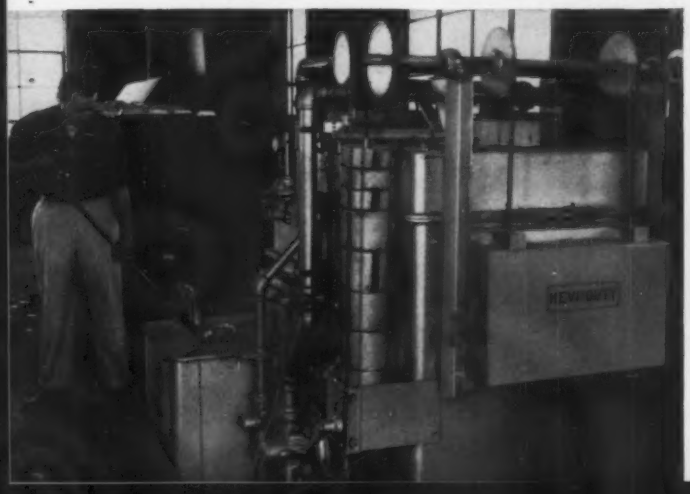
B P C

A Division of Basic Products Corporation

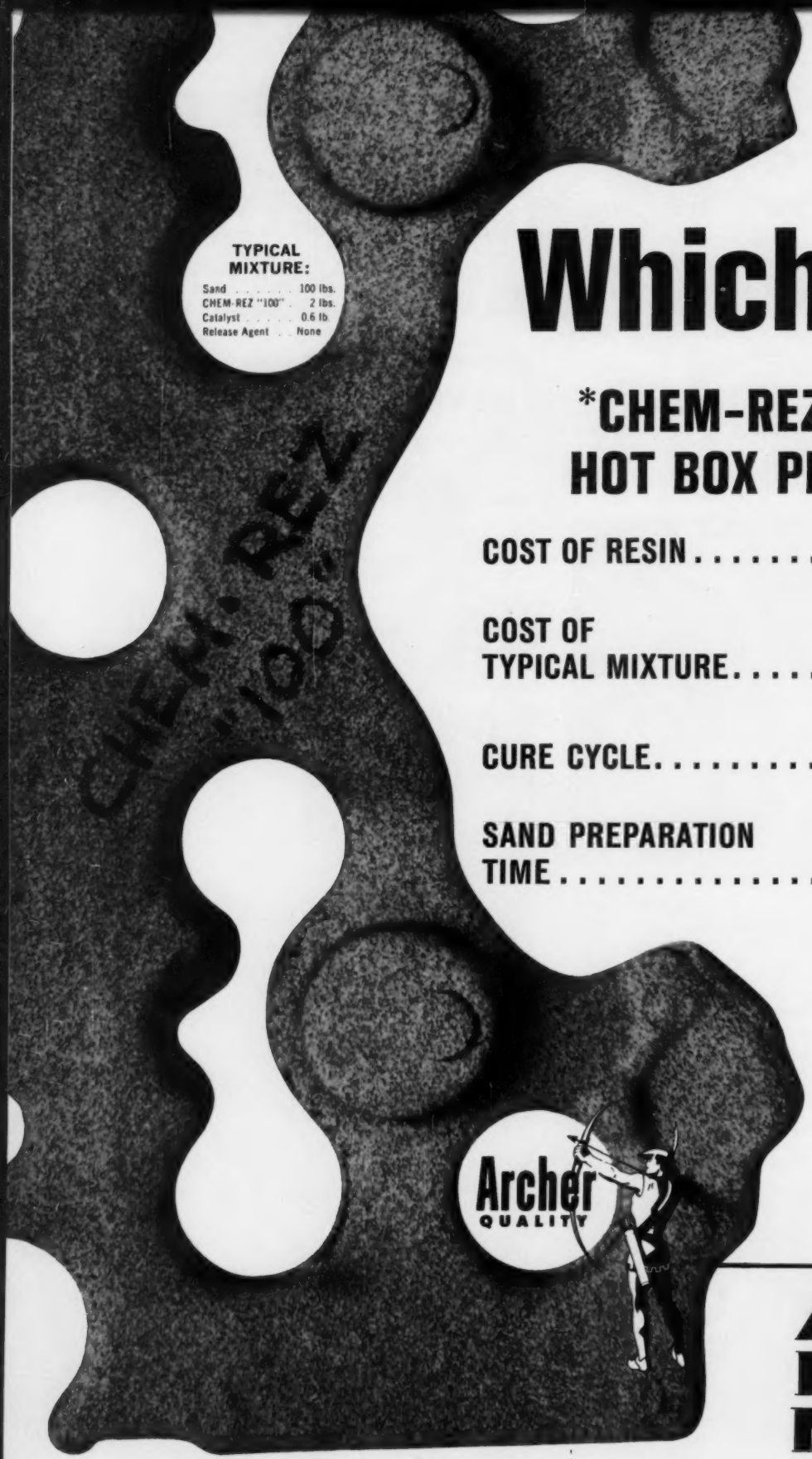
Hevi-Duty Electric Company, Milwaukee 1, Wis.

This electric crucible furnace is used by Baso, Inc., Milwaukee, Wisconsin, for holding aluminum at 1240°F. Baso casts components for controls for all types of gas burning equipment from permanent molds. Circular design allows three dip-out stations. There are no exhaust fumes, no bath turbulence, and exterior shell remains relatively cool. ***For complete information on this furnace, write for Bulletin 591.***

Elm City Pattern and Foundry Works, Branford, Conn., uses this dry hearth furnace for sand casting aluminum. Mr. Hal Burkehard, Foundry Manager, likes the way the thermocouple control holds the bath at uniform temperature. He reports that this unit produces cleaner castings than do their other furnaces . . . that he gets only a handful of dross from a 500-lb melt. ***Please request our Bulletin 594.***



A gas-fired, double chamber dry hearth furnace is used for die-casting electric frying pans at the New England Die-Casting Company, West Haven, Conn. Aluminum melts on a sloping hearth and runs into a dip-out chamber where it remains at constant casting temperature. Moisture and volatiles escape during heating. Foreign materials remain on the hearth. This assures clean, high-quality metal on a production line basis. ***Please write today for Bulletin 594.***



Which core

*CHEM-REZ "100" HOT BOX PROCESS?

COST OF RESIN . . . . . 16.3¢ per lb. delivered**

COST OF TYPICAL MIXTURE . . . . . 37.4¢ per 100 lbs. of sand

CURE CYCLE . . . . . 30 sec. at 400 to 450°F.

SAND PREPARATION TIME . . . . . 1½ to 3½ minutes

Other cost-saving benefits of CHEM-REZ "100":

- Existing core blowers and sand mixers can be used.
- Positive collapsibility; fast, complete shakeout.
- Clean, safe working atmosphere.
- Process is easy to install.

Archer-Daniels-Midland

*In Canada, manufactured and sold under the trade-name, ADMIREZ "100".
**East and North of Kansas City. Price subject to change without notice.

Circle No. 157, Page 161

costs less?

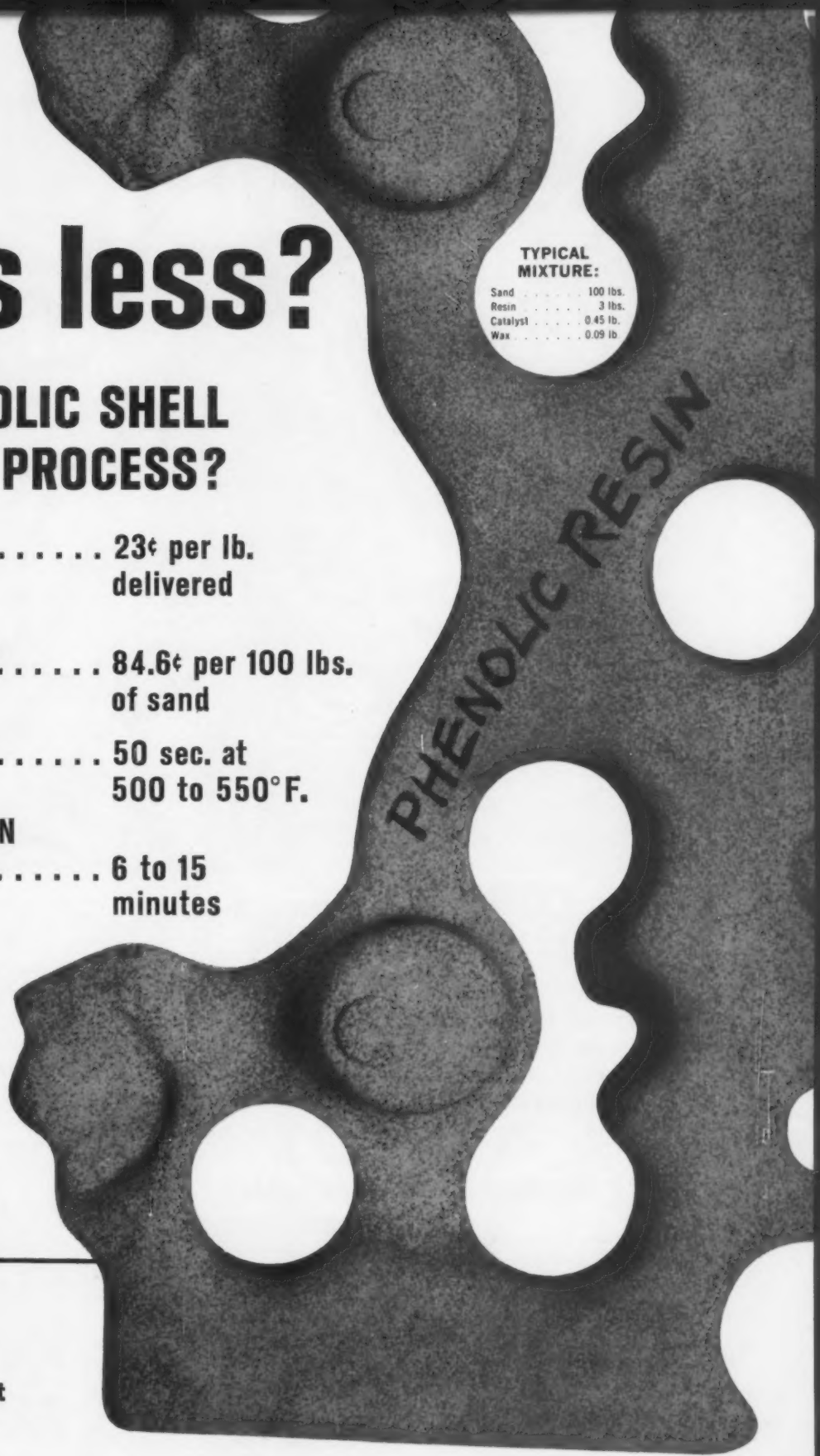
PHENOLIC SHELL CORE PROCESS?

COST OF RESIN . . . . . **23¢ per lb. delivered**

COST OF TYPICAL MIXTURE . . . . . **84.6¢ per 100 lbs. of sand**

CURE CYCLE . . . . . **50 sec. at 500 to 550°F.**

SAND PREPARATION TIME . . . . . **6 to 15 minutes**



Get more facts about CHEM-REZ "100" from your ADM MAN, or write for technical bulletin. A complete line of ADM resins, binders, clays, and facings is available for every foundry process.

FEDERAL FOUNDRY

SUPPLY DIVISION

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Cleveland 2, Ohio

VOTE for Cleaner Iron

VOTE for...

***Famous* CORNELL CUPOLA FLUX**

for Gray Iron and Malleable Iron Foundries

Each day more and more foundrymen vote for the flux of their choice, Famous Cornell Cupola Flux. This famous flux produces cleaner metal, reduces scrap losses, gives greater tensiles, increases fluidity of slag, saves many hours of digging out time because drops are cleaner. And Famous Cornell Cupola Flux costs only pennies a day.

"often imitated but never equalled"

Try Famous Cornell Aluminum, Copper and Brass Flux, too. Write for Bulletin 46-A.

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Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes—Since 1918

Circle No. 148, Page 161

Reader Opinions . . .

Continued from page 12

ulate you on the very great improvement in MODERN CASTINGS. The transformation has been extremely well done.

CARL H. BURTON
Aluminum Smelters
Research Institute
Chicago

Editor's Note: Thank you for clarifying the somewhat confusing situation over the status of aluminum exports. I'm sorry if we seemingly misrepresented the dilemma.

THANKS FOR PHOTOS

Enclosed are the photographs you so kindly forwarded to us earlier this year. We have also enclosed a copy of our summer, 1960, issue of our external publication in which one of the photographs was used to illustrate the CO_2 process in our story, "Silica in the Foundry."

Thank you again for your cooperation in forwarding these photographs for our use.

L. G. BURWINKEL, JR.
Pennsylvania Glass Sand Corp.
New York

Editor's Note: Anyone needing good foundry photographs to illustrate articles, books, talks, etc., feel free to contact MODERN CASTINGS. *We will be glad to help you in anyway possible.*

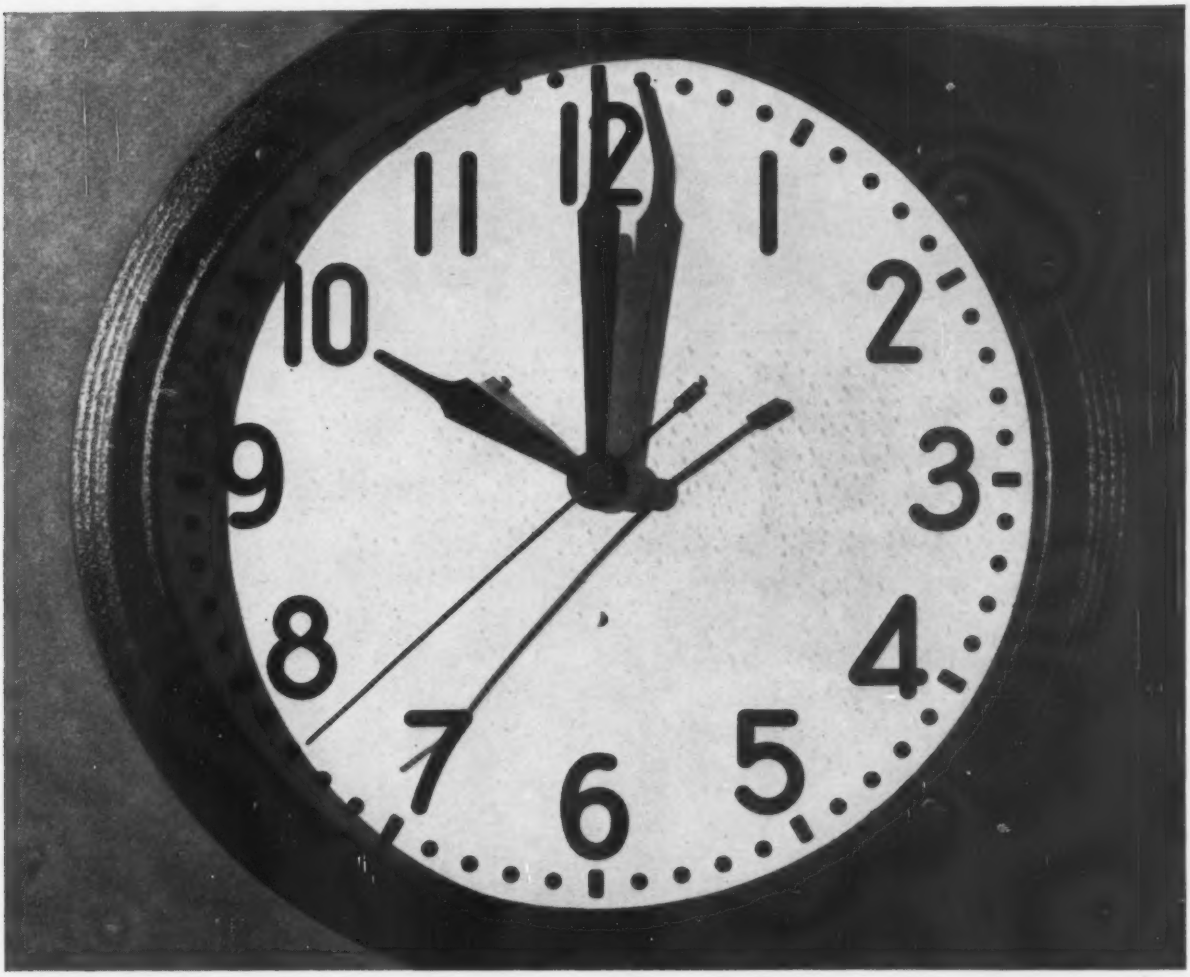
CLIFFORD B. CORNELL

It is with deep sadness that I announce the news, with which you no doubt are already familiar, that Mr. Clifford B. Cornell died Aug. 3.

Mr. Cornell was well known in the foundry industry, very popular, held in the highest esteem by all those who came in contact with him through his 46 years as founder and owner of Cleveland Flux Co., Cleveland.

FRANK P. VOLGSTADT
Cleveland Flux Co.
Cleveland

EDITOR'S NOTE: The Cornells, originally residents of Canton, Ohio, moved to Pittsburgh in 1916 and Cleveland in 1918. In the latter year they formed Cleveland Flux Co. with the father, John C. Cornell as president and Clifford B. Cornell as secretary. The business was founded on formulas developed years previously by the father who had been a foundryman. Upon the death of John C. Cornell in 1925, Clifford Cornell became the sole stockholder and took on the duties of secretary-treasurer.



Your Inco Distributor beats the clock with "on-time" deliveries

You can count on your nearby Inco Distributor for "on-time" delivery of the form of Inco Nickel best suited for your own foundry needs.

You can also count on him for technical assistance to help solve your production problems.

Your Inco Distributor understands how much your profits depend upon getting the alloying elements you need . . . when you need them. That's why he's set up to supply high-purity Nickel right from his warehouse stock.

Whether you're producing nickel cast iron, nickel alloyed steel, heat-and corrosion-resisting castings or nonferrous castings—your nearby Inco Distributor has the form of Inco Nickel best suited for your use and in the quantities you need. His staff of Practical Foundry Specialists can help you solve your problems involving alloy selection and production methods.

Your Inco Distributor can help you beat the clock with "on-time" deliveries, with technical assistance that has already helped solve problems similar to your own. It will pay you to call him today. The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

INCO NICKEL

NICKEL MAKES CASTINGS PERFORM BETTER LONGER

INCO FOUNDRY PRODUCTS ARE DISTRIBUTED BY:

PACIFIC METALS CO., LTD.—San Francisco, Los Angeles, Salt Lake City

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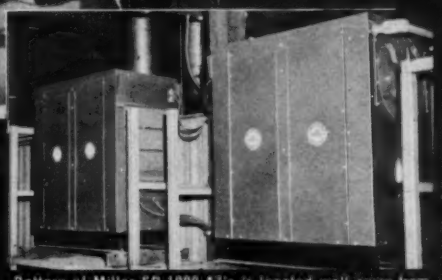
WILLIAMS & COMPANY, INC.—Pittsburgh, Cleveland, Cincinnati, Columbus, Toledo, Louisville

Foundries Find

miller-powered carbon arc cutting

Faster — Cheaper — Better

These photos, taken in well-known foundry, show operator carbon-arc cleaning a casting using an Arcair torch powered by a Miller SR-1000-A7. Note handiness of control console.



Battery of Miller SR-1000-A7's is located well away from cleaning room.

THE MILLER MODEL SR-1000 series, providing 1000 amperes of d-c at 40 arc volts, 100% duty cycle, has proved to be the ideal power source for Arcair and other foundry carbon arc cutting processes. Designed and built around Miller's exclusive semi-metallic, completely sealed Gold Star rectifier, drastic overloads are handled routinely without failure or deterioration. Control console is instantly removable to any reasonable distance. Adjustment of current range from 200 to 1400 amperes is accomplished under load. What's more, the operator can switch in a flash from cleaning and gouging to welding when needed. Operates from three phase power lines.

For applications involving carbon arc cutting, heavy submerged arc welding, plasma jet and electric furnace processes, the Miller SR-1000 series is probably without an equal. May we send you more complete details and specifications?

MODEL SR-1000-A7

miller ELECTRIC MANUFACTURING COMPANY, INC.

Distributed in Canada by Canadian Liquid Air Co., Ltd., Montreal

APPLETON, WISCONSIN

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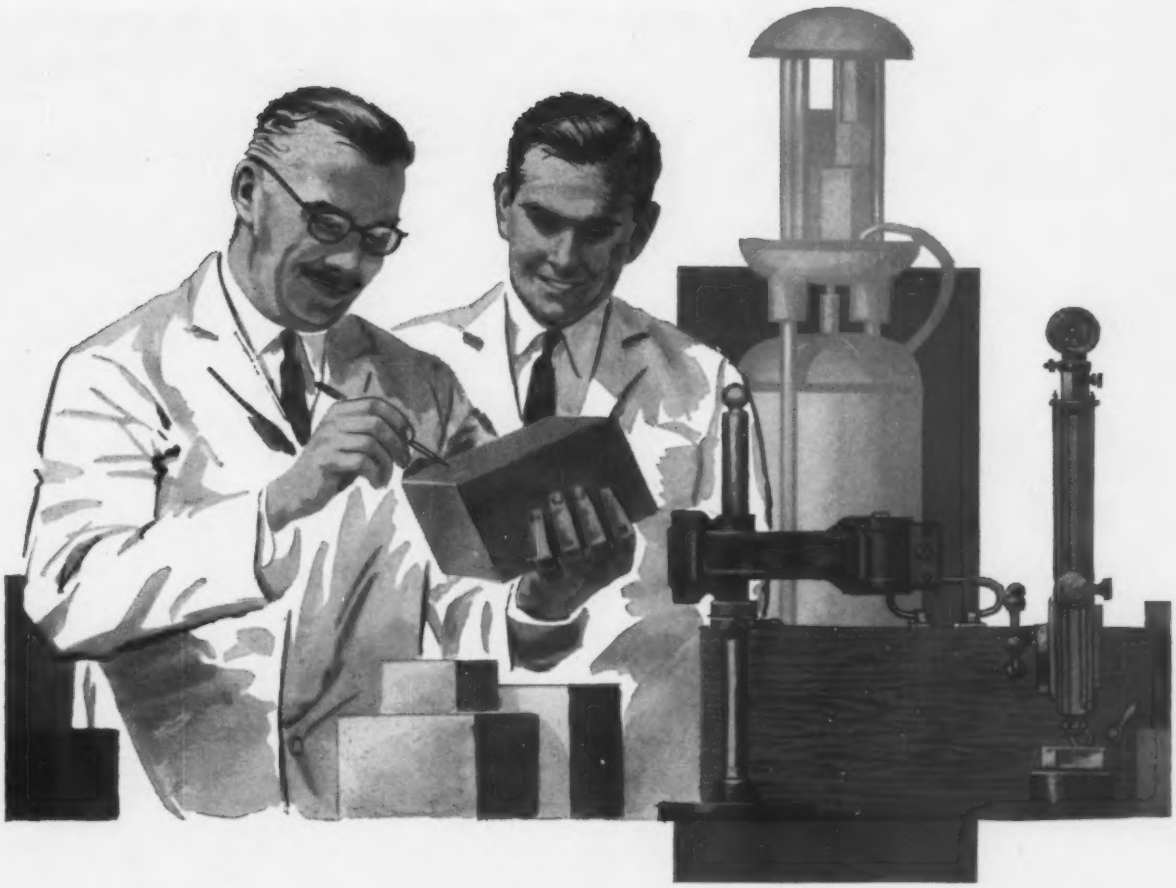
Molybdenum and reliability go hand in hand



Through the years, iron and steel producers have recognized molybdenum as an alloy giving assured results in producing higher than normal properties every time. "Moly" is compatible with other elements which may be commonly used, such as nickel, chromium or vanadium.

In high temperature alloys and corrosion resistant steels, Moly's use has long proven most acceptable. It endows steels with air hardening, increases the depth of hardening, is responsible for an increase in low temperature impact properties, and possesses ability to increase wearing qualities.

Especially to those contemplating new heat treatment or design, molybdenum affords a proven usefulness in assuring desired results. MCA's vast experience in the use of alloys is yours for the asking. If you have a question about molybdenum's potentialities in any ferrous product, write today for the latest technical help.

MOLYBDENUM

4 Gateway Center CORPORATION OF AMERICA **Pittsburgh 22, Pa.**

Offices: Pittsburgh, Chicago, Los Angeles, New York, San Francisco
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

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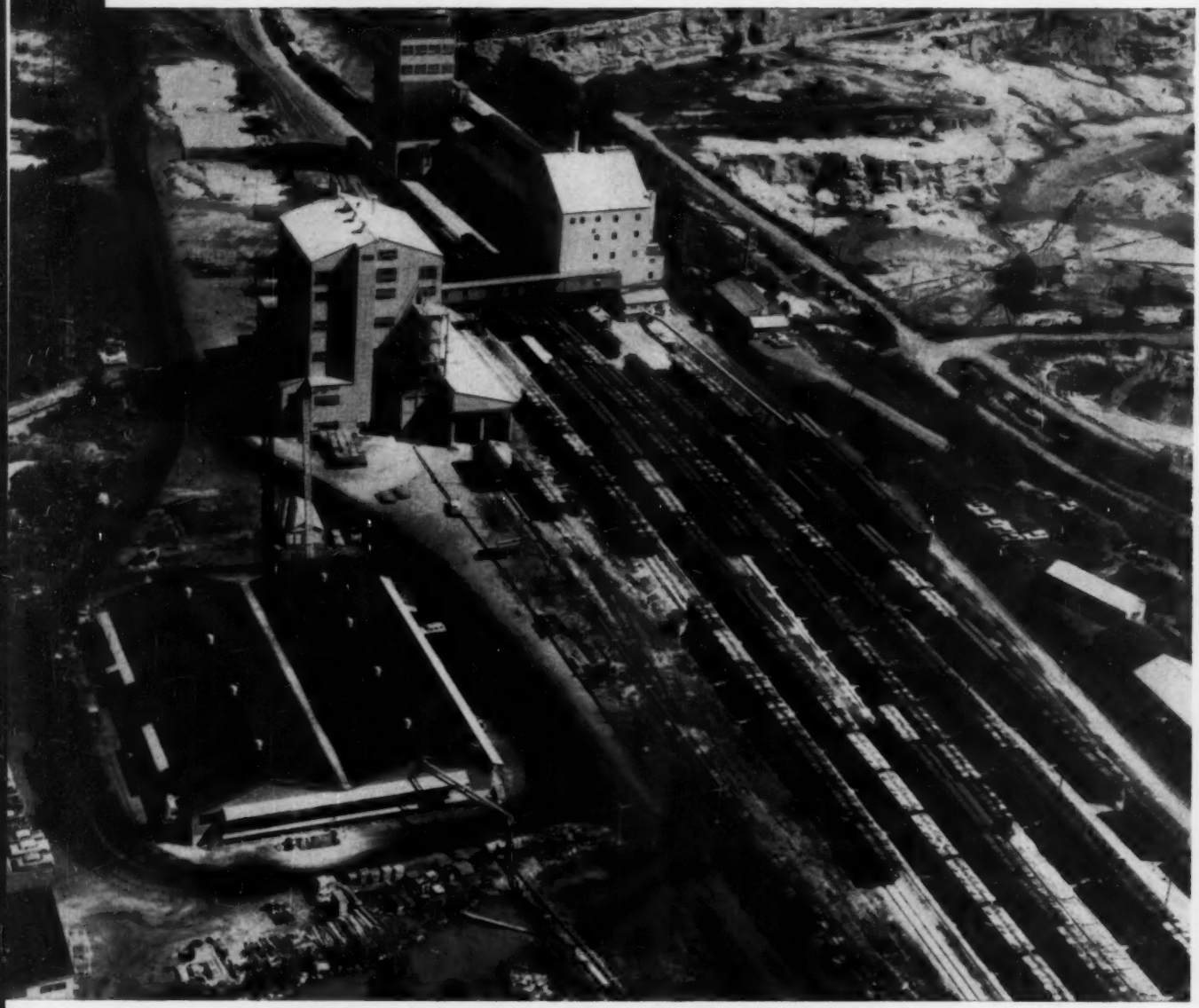
Better castings start here...



...modern production facilities to supply the nation's steel and foundry industries with large (and small) tonnages of purest quartzite.

IDEAL FOR CORES AND MOLDS—excellent flowability . . . highly permeable . . . low oil and bond requirements . . . can be re-used more times than ordinary foundry sands (Ottawa's hard, round-grain silica holds up better under all types of reclamation systems. Smooth surfaces clean easily—no crevasses or cleavage planes. Fewer original binders to remove).

REDUCE YOUR TOTAL SAND COSTS AND CASTING REJECTS—SWITCH TO OTTAWA SILICA!

Circle No. 144, Page 161

OTTAWA SILICA

HYDRAULIC MINING

DRAIN BINS

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QUALITY CONTROL LAB.

MAIL US YOUR TYPE OF METAL AND SIZE OF CASTING SECTION. WE WILL BE HAPPY TO SEND OUR RECOMMENDATION FOR GRAIN SIZE

99.9% PURE SILICA

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Circle No. 144, Page 161

MEASURE
HEAT
ACCURATELY
with

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PYRO OPTICAL PYROMETER

The only self-contained direct-reading optical pyrometer for quick temperature measurements of molten iron, steel, monel, etc.

Send for catalog No. 85.

the universal

PYRO SURFACE PYROMETER

Rugged, easy to read. Ideal for shell molding, core oven, mold and die surface temperature measurements. Single and double ranges from 0-300°F to 0-1500°F.

Send for catalog No. 168.

PYROMETER INSTRUMENT CO., INC.
BERGENFIELD 10, NEW JERSEY

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DIETRICH'S CORNER

MATERIAL CONTROL— A FOUNDRY FARCE

by H. F. DIETRICH

When asked what is the most important factor in modern industrial development, most foundrymen will tell you that it is material control. We make analyses of everything—that is *almost* everything. We analyze clay, sand, metal, and even the human element. Yet, there are many factors in industrial operation which we ignore.

In our statistical records, we pretend that they don't exist. Or we provide a column for unknowns as a catch-all for things that would upset our quaint bookkeeping system. While the customer accepts our castings, there is no point in opening this Pandora's box of unknown equations.

Perhaps one of the most amusing aspects of this lopsided control is in the melting department of a foundry. I've seen chemists set up carbon trains that would be a credit to the late Rube Goldberg; run sulphur and manganese titrations that were a work of art; burn off silicon and weigh it with a chain balance; and do a triple flip with a side twist if the pig iron came in 10 points off their specifications. Yet, in the back yard, the charging crew was throwing everything into the stack that wouldn't fight back.

Every foundryman likes to brag about the control he has over his melting operation. His metal is always hot enough to pour needles, and his fuel consumption is always low. Just how little fuel he uses depends on who tells the first story.

One foundryman of my acquaintance proudly stated that he was running three garbage cans full of coke between charges in a 48-inch stack. On the surface, this sounded a bit silly. Now, when I have had a chance to think it over, it doesn't seem as silly as the method used by most foundries of that day. The usual practice was to throw in a certain number of *forks* full of coke with each charge. The amount you got into the furnace depended on how much ambition the charger could generate. The garbage can was at least a volume measurement that was far more consistent than the fork.

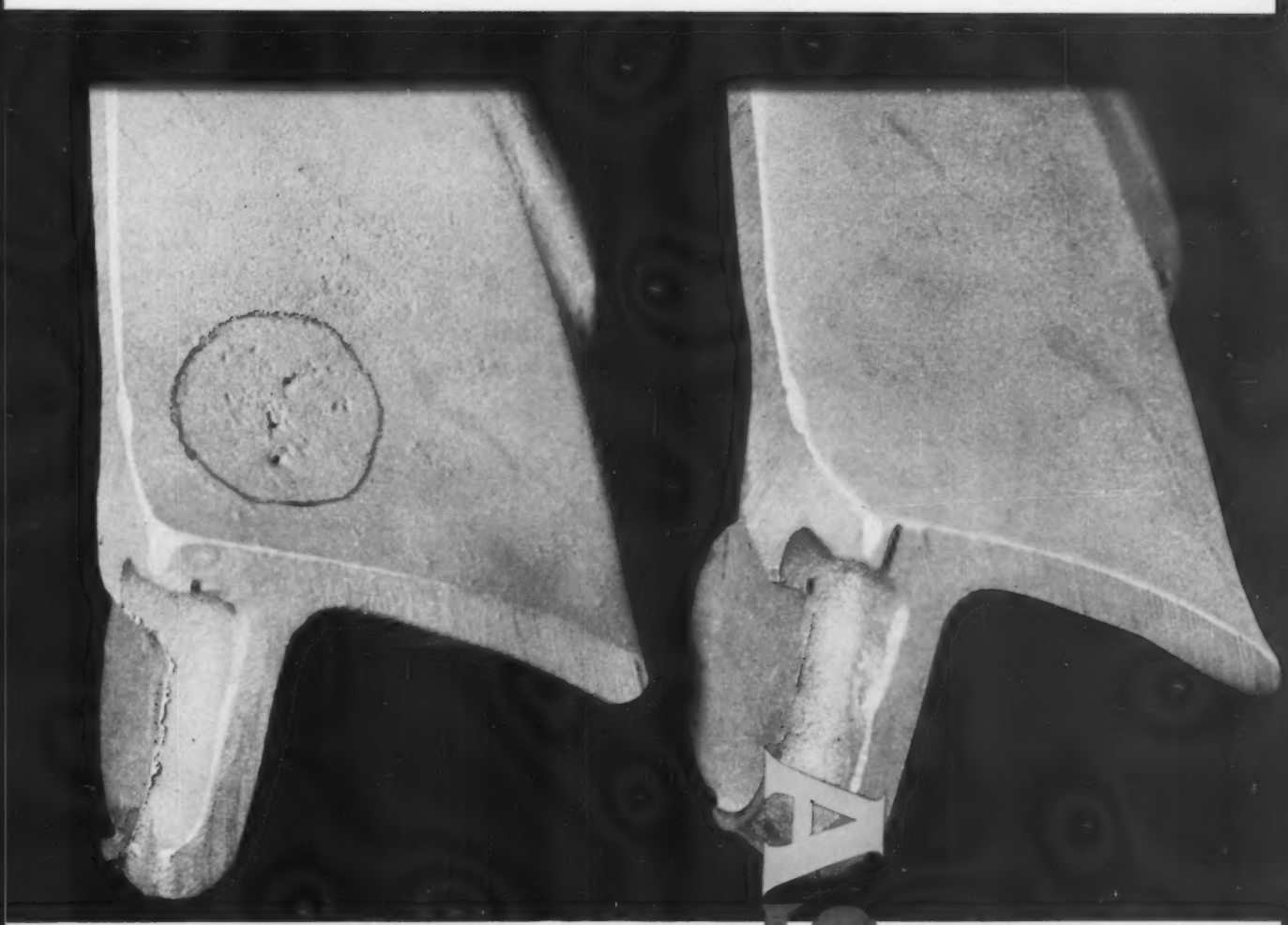
Another amusing foundry control system was brought to my attention just a short time ago when I visited a small foundry. On the wall of the core room, just above the sand conditioning machine, was a blackboard on which was written the various core mixes. The amounts of ingredients were given in number of *cans*. There were a certain number of cans of cereal binder, iron oxide, kerosene, core oil, and, under all this, a certain number of cans of chopped nuts. In all of my foundry experience, I have never used chopped nuts in core mixes. It seems there must be a humorist in every foundry crew.

Now, about this can business; suppose some wheelbarrow pilot runs over the can. What would happen to the measurement? Surely, the sandmuller engineer must have flunked physics twice, or he wouldn't be on that job. He shouldn't be expected to know that the can won't hold the same amount after he straightens it. So, until it is discovered in the foundry, the core mixes will be wrong for the job.

If, instead of a wheelbarrow, a lift truck rolled over the can, the core room would be out of business until someone opened another can of beans. This might be of a different brand and size, but as far as the blackboard is concerned, the measurement of a certain number of cans would be right.

All of this is not an argument against controls in the foundry. But if we are going to have controls, they should be complete and done by some standard measurement. There seems to be something wrong with a report that gives us the amounts of Si, C, P, Mn, and S, in gray cast iron, and leaves out the many other elements which might be present to affect the structure. If you throw everything into the charging door except the foundry cat, you are bound to get more into the casting than shows up in the routine test tube.

Some foundrymen believe that a *little* control is better than *none*. Is it? Isn't it like sleeping on *one* feather and expecting to get a small amount of comfort?



Now ASARCO process reduces and controls shrinkage

FEDERATED PT (pressure-tight) ALUMINUM CASTING ALLOYS

Use PT-processed metal instead of any of the standard sand and permanent mold aluminum casting alloys. Result: no unpredictable shrinkage. No need for extra gates and risers. Higher yield per pound of metal. More uniform pressure-tight castings. A brighter cleaner surface. All the same physical and mechanical properties and characteristics. Write or call today for full information about PT grade aluminum, to Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, RE 2-9500; or call your nearest Federated sales office.

Comparative photograph illustrates the effect of PT treatment. Casting on left from standard aluminum alloy, shows typical shrinkage over a large area. Compare with casting on right, cast in PT grade, under the same conditions! Alloy: F460 (319)

ASARCO

AMERICAN SMELTING AND REFINING COMPANY

FEDERATED METALS DIVISION

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IN CANADA: Federated Metals Canada, Ltd.
Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

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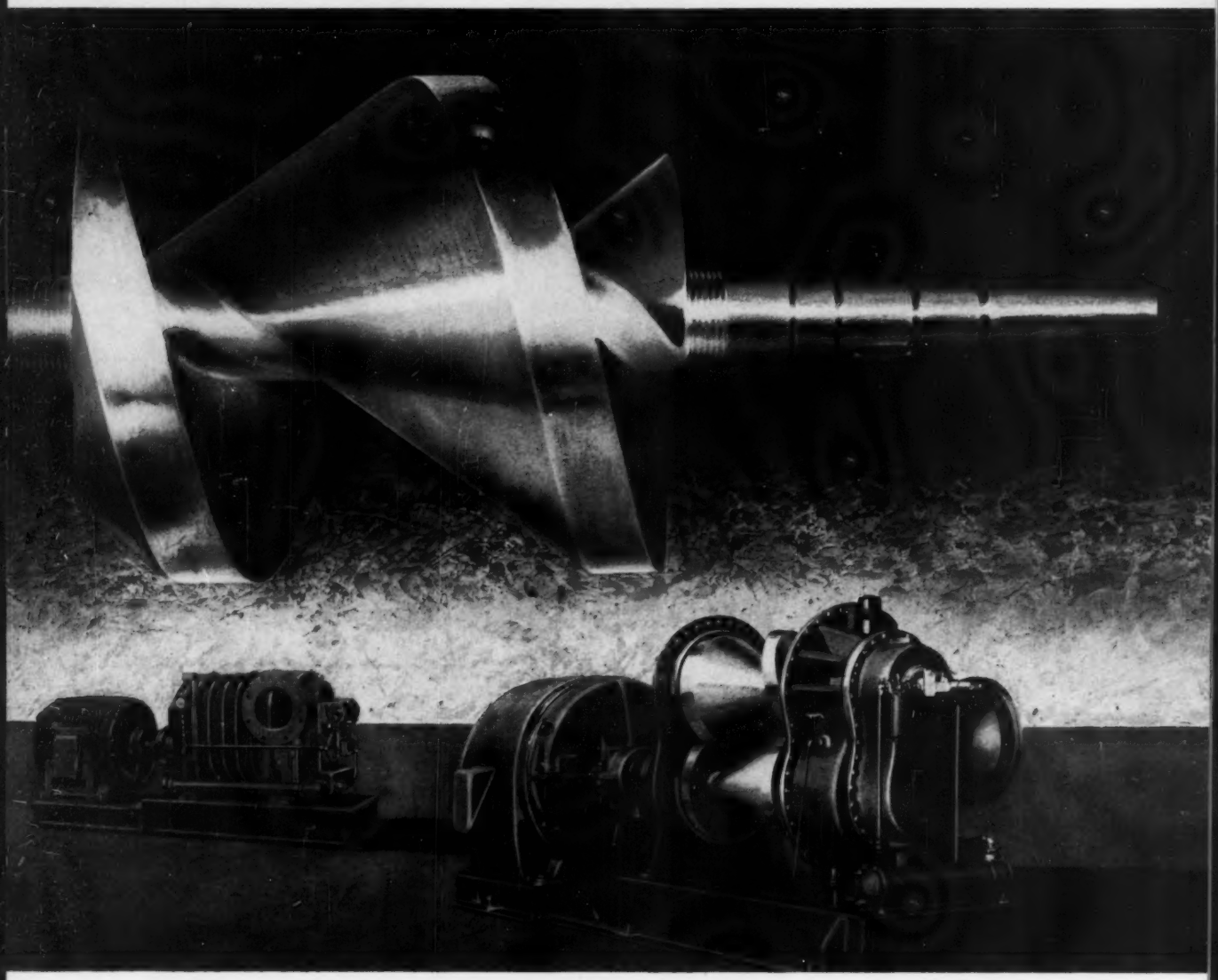
How the Foundry Industry Serves America . . . #10 of a Series



CAST IRON ROTORS IMPROVE COMPRESSOR DISPLACEMENT 41%, REDUCE COST 29%

The original design of this air compressor called for forged steel shafts with pressed-on rotors, requiring a rotor hub large enough to key it to the shaft. This unit was subsequently re-designed to provide for integral-cast rotors and shafts which permitted smaller hub diameters and correspondingly larger rotors in the same cylinder. Displacement was improved by 41%. Lower cost of materials, less machining and shortened assembly time resulted in a 29% cost saving, as well.

Here is just one more impressive example of how the intelligent use of versatile iron castings by industrial designers can increase product efficiency and at the same time substantially reduce fabrication costs.

For the production of structurally sound iron castings, Hanna Furnace provides foundries with all regular grades of pig iron . . . foundry, malleable, Bessemer, intermediate low phosphorus, as well as HANNA-TITE® and Hanna Silvery.

Facts from files of Gray Iron Founders' Society, Inc.

HANNA
THE BEST KNOWN NAME IN IRON

THE HANNA FURNACE CORPORATION
Buffalo • Detroit • New York • Philadelphia

Hanna Furnace is a division of **NATIONAL STEEL CORPORATION**

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In the interest of the American foundry industry, this ad (see opposite page) will also appear in

STEEL
IRON AGE
FOUNDRY
AMERICAN METAL MARKET

How the Foundry Industry Serves America . . . #10 of a Series
CAST IRON BUYERS IMPROVE COMPRESSOR DISPLACEMENT 41%, REDUCE COST 25%
YOUR NAME HERE

FREE!

REPRINTS OF THIS AD WITH YOUR FIRM'S SIGNATURE

If you would like to have reprints of this ad to mail to your customers and prospects, let us know. Reprints will have no Hanna product message or signature, but will be imprinted with your firm name and address. Absolutely no obligation. To order your reprints, fill in and mail the coupon below.

The Hanna Furnace Corporation
Detroit 29, Michigan

Please send me_____reprints of Ad No.
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____of your Foundry Industry Series.
Imprint as follows:

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I understand there is no charge for this service.

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SAFETY–HYGIENE–AIR POLLUTION

The Foundry Buffoon– An Industrial Menace

by HERBERT J. WEBER

Some time ago a Detroit newspaper carried a story about a maintenance man who climbed inside the concrete mixer of a ready-mix truck to do some repairs.

The driver of the truck, having a reputation as a practical joker, then decided to throw the mixer in gear for laughs. The maintenance man was mangled to death.

When the police asked the unfunny joker why he did such a thing, he answered, "I just wanted to see what would happen." Yes, that story is true!

We have similar clowns in the foundry who insist on being the show-off or the life of the party. Like spoiled kids, they want to draw attention to themselves . . . they want to be noticed. Following are some true accounts of these menaces.

There is the "look-ma-no-hands-type" of lift truck driver. One of these show-offs was driving his truck at full speed with his hands placed behind his head to show his skill. The truck ran over a casting causing the truck to swerve into a pit mold. The driver smashed his leg and the mold too. THE MOLD DAMAGE IS REGRETTABLE.

The Yo Yo crane operator is particularly funny.

This type of clown takes a ladle of molten metal down the bay and by adroitly jerking the crane, gets the ladle to swing in pendulum-like fashion. One of them, while playing Yo Yo, struck a pile of flasks and splashed metal on two men, causing severe burns.

The lunch box joke always draws a laugh but sometimes a broken toe or sprained back. In this comedy scene, a molder's lunch box was emptied and lead pigs put in. At noon time, the molder picked up his lunch box but was off balance and the unexpected weight caught him unprepared. The sudden twist sprained his back and he was off work for a week.

Another hilarious joke was pulled by a crane operator who was holding a ladle of metal on the hook while the man below was skimming it. The crane man threw the aluminum foil from a cigaret pack into the ladle . . . just for laughs. The sudden flash caused the skimmer to jerk the skimming bar and he got a splash of hot slag on his face.

Then there were the two buffoons who used to turn off the exhaust system over the degreasing tank just to watch the elderly degreaser operator get drunk from the vapor and stagger around. The humor in this lay in the fact that the old man was a teetotaler. It was fun to make him drunk. One day the jokers left the exhaust off.

Now let me tell you about the spit fire trick. As you know, phosphorus, when exposed to air, will ignite spontaneously. Hence it is kept in water.

In order to make phosphor copper, a stick of phosphorus is taken from a water container and rapidly plunged into molten copper.

The man doing this job in a certain foundry used to show off in front of visitors by putting a small piece of phosphorus in his mouth and spitting it out just in time to ignite as it hit the floor. The scene is dramatic. This man spits fire.

One day, his timing was off and he burned a nice hole in his jaw.

I must tell you also about the hot-stream trick. In this display of daring, the show-off runs his finger rapidly through a stream of hot metal without getting burned. This can really be done if the finger is turned out and down.

However, one ham actor tried it with the finger turned out and up. He caught a pool of metal in the palm of his hand.

The Haynes Stellite Co. of Kokomo, Indiana, holds the best all-time, no-injury safety record known in the foundry industry. This foundry has operated 7,407,010 continuous man-hours without a disabling injury.

I don't think that record would be possible if the company had buffoons on the payroll.

NEWEST MEMBER

of The Quaker Oats Company CHEMICALS DIVISION

QO FURSET BINDER

QO FURSET provides

SPEED • Cores of high strength can be produced in 15-30 seconds in hot core boxes.

CONVENIENCE • Just mull QO FURSET with sand and it is ready to use.

ECONOMY • QO FURSET is inexpensive and cores made with it produce low cost castings.

QO FURSET Binders are suited for both ferrous and non-ferrous foundries and can be adapted to conventional (high green strength) production as well as hot core box work. Your letter will bring Bulletin 501-A and technical assistance. Write today.

The Quaker Oats Company
CHEMICALS DIVISION
338M The Merchandise Mart, **Chicago 54, Illinois**
Room 6158M, 815 Superior Ave., **Cleveland 14, Ohio**
Room 538M, 120 Wall Street, **New York 5, New York**
Room 438M, 48 S.E. Hawthorne Blvd., **Portland 14, Oregon**
Quaker Oats Ltd., Bridge Road, **Southall, England**

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SELECT THE RIGHT MEN

by RALPH BETTERLEY

Last month ten points were briefly covered relative to industry's more effective use of outside training services. (See MODERN CASTINGS, September, page 25). Here, in greater detail, is an elaboration on point No. 5—*Select the right men.*

The foundry industry is utilizing out-of-plant training programs effectively; however, the above subject should undergo close scrutiny if optimum results are to be achieved. In *selecting the right man,* foundry management should not divorce from this decision the importance also of simultaneously weighing three more *rights*: (1) the right course, (2) the right time, and (3) the right reasons.

Personnel qualifications and interests should be carefully considered for a specified course or program. Indiscriminate personnel selection can be a costly and unproductive policy, both from the personal as well as the company's standpoint. Courses selected should parallel a candidate's experience, education, and background if instruction is to be most effective. Management or the company training director should analyze the level of instruction offered and how it "fits in" with the prospective student's position, potential, and goals.

There is nothing more pathetic and frustrating than the "out-of-place" student struggling with a technical presentation. Haphazard selection of candidates can result in unqualified students being "snowed" and, conversely, more advanced personnel should not be subjected to basic and elementary programs.

Training programs outside of the plant should not be taken lightly as a mere company-paid vacation. And students accepting these assignments should realize they have an important obligation to their management when they return. Only candidates willing to accept such responsibilities should be seriously considered for these growth opportunities.

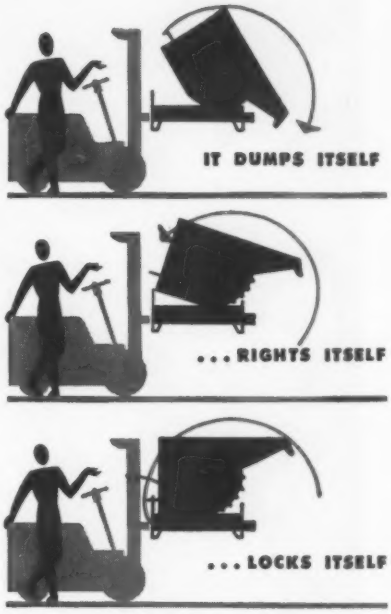
The Training and Research Institute of the American Foundrymen's Society has been satisfied and amazed, far beyond original expectations, with the attitudes, diligence, and scholarly interest shown by the high-calibre participants in this program. Foundry management deserves credit for utilizing this training medium for the *right* people.

With limited facilities and courses many such technical courses must, by necessity, keep the level of instruction on a "medium" plane. Every attempt is made in AFS-T&RI courses to avoid "swamping" the less-experienced student, and at the same time "challenging" the more advanced candidates.

Realizing at this point that matching courses of outside organizations with plant personnel is of vital importance, foundry management should plan and schedule such projects well in advance of course dates. Impulsively registering personnel because of availability at the time jeopardizes a company's position for maximum benefit from this technical assistance. When programs are considered early and matched to specific key personnel, both the plant and the participants are in a more favorable position to gain from the information presented.

From this standpoint, personnel should be advised early of available courses. Making this information available to them capitalizes on the most important necessity for successful training and growth—*desire*. Certainly foundries should go all out to match courses to people who *really want to learn*—improve their positions—and develop with increasing responsibilities in the plant's operations.

Out-of-plant courses are useful tools and can aid foundries in improving the productivity of their personnel. But, when scheduling such programs for expensive manpower, it should not be forgotten that a "round" peg in a "square" hole makes a poor fit. Thus training the *right* man with the *right* program can give you more mileage with your *training dollar*.



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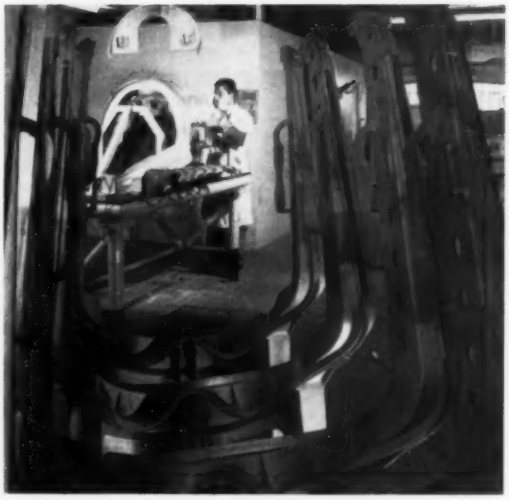
. . . 1430 curies of cobalt 60 is being used by Quaker Alloy Casting Co., Myerstown, Pa., to guarantee sound stainless and high alloy steel castings. This is the largest gamma radiography facility ever sold. The unit, called a Gammatron and manufactured by Radionics Inc., Norristown, Pa., contains the equivalent of $40 million worth of radium, but sells for less than $20,000. Besides introducing higher quality into the radiographs, the camera speeds inspection.. As little as five minutes is ample time to radiograph eight-inch thick sections of steel. Previous equipment required many hours to make a single exposure.

Here's How . . .

Each month this department brings you the newest developments in the foundry industry. These represent, in the opinion of the editors, ideas and applications which may help you perform a better job.



. . . A sand-cast aluminum-magnesium alloy canopy frame is checked to meet tolerances within 1/10,000 of an inch before installation on the Republic F-105 D all-weather fighter-bomber. Cast by R. H. Osbrink Mfg. Co., Los Angeles, these frames are said to be lighter and stronger than those made by conventional fabrication techniques. These aircraft castings also pass rigid x-ray inspections.

DIXIE BOND—famous for flowability, green strength, permeability

PEPS UP MOLD PRODUCTION

The sandbox crowd doesn't understand flowability, but they know its feel. Important as this bond clay characteristic is, it's only one of the "extra benefits" you get with Dixie Bond.

Gray iron, malleable, steel, brass and aluminum foundry folks know Dixie Bond for its most famous fe..ture — highest green strength clay available! Other "extra-benefit" features that pay off in pepped-up mold production and improved casting finish include:

- reduced shrinks and draws
- fewer broken or cracked castings
- less core sag or out-of-round cores
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- reduced need for core wires and driers

You'll find that these Dixie Bond characteristics improve operations all along the line. A call to your IMC service engineer will bring you more Dixie Bond advantages: easy shakeout with less lumping, better knockout, reduced flask maintenance, and other casting features.

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ADMINISTRATIVE CENTER, OLD ORCHARD ROAD, SKOKIE, ILLINOIS, ORCHARD 6-3000

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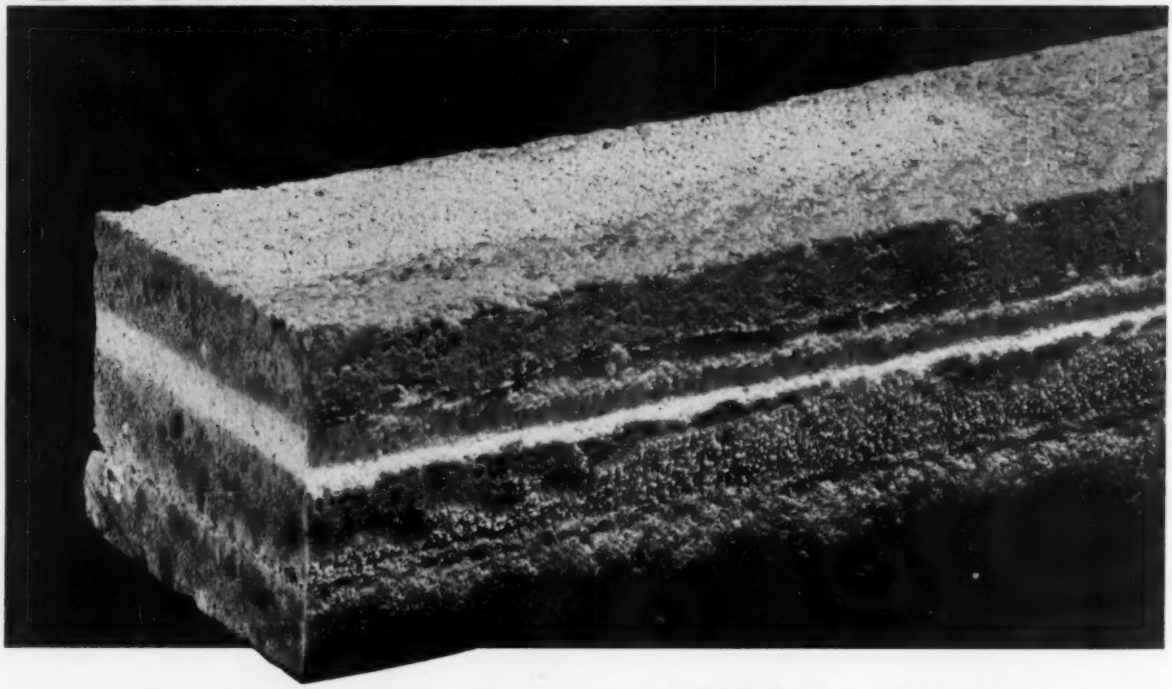
TRIAL BY HEAT...



Superior Refractoriness of TASIL 301 Cement proved by severe test

TEST DETAILS...

Three slices of TAMUL brick were cemented together with approximately ¼" thick joints—one of TASIL 301 Cement, the other a widely used fire clay base high temperature cement. After drying, an 11-lb. brick was placed on top of the specimen which was then put in a laboratory re-heat furnace. The specimen was fired to 3000° for five hours, then allowed to cool. The brick was then sectioned, as shown.

Get TASIL Special Refractory Cements in the form you prefer:

No. 301 Air-Setting Cement—ready-mixed in drums.

No. 317 Air-Setting Cement—dry in bags.

No. 302 Heat-Setting Cement—dry in bags.

After five hours at 3000° temperature, the TASIL mortar in this test "sandwich" was unaffected. In the other joint, the cement has melted and run out—permitting the brick to press completely together.

New improved TASIL 301 Cement was developed to pass these specifications:

- **Superior refractoriness... high bonding strength ... improved workability... minimum shrinkage at high temperatures... maximum resistance to slagging and erosion.**

Get maximum joint protection by using TASIL 301 Cement for your next furnace rebuild.

Call in your Taylor Field Engineer, or write direct for details.

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New Ferrocarbo Briquettes* are the only cupola deoxidizers containing an expanding agent, a catalyst and a slag activator. Ferrocarbo Briquettes enable progressive foundrymen to obtain castings that are stronger, denser and more easily machinable. In addition, the use of Ferrocarbo® promotes more thorough deoxidation, improved fluidity, greater silicon efficiency, reduced sulfur, better manganese recovery, fewer scrapped castings.

CARBORUNDUM®

**Patent pending.*

Ferrocarbo® distributors are Kerchner, Marshall & Company; Pittsburgh, Buffalo, Detroit, Philadelphia, Birmingham, Los Angeles, Canada.
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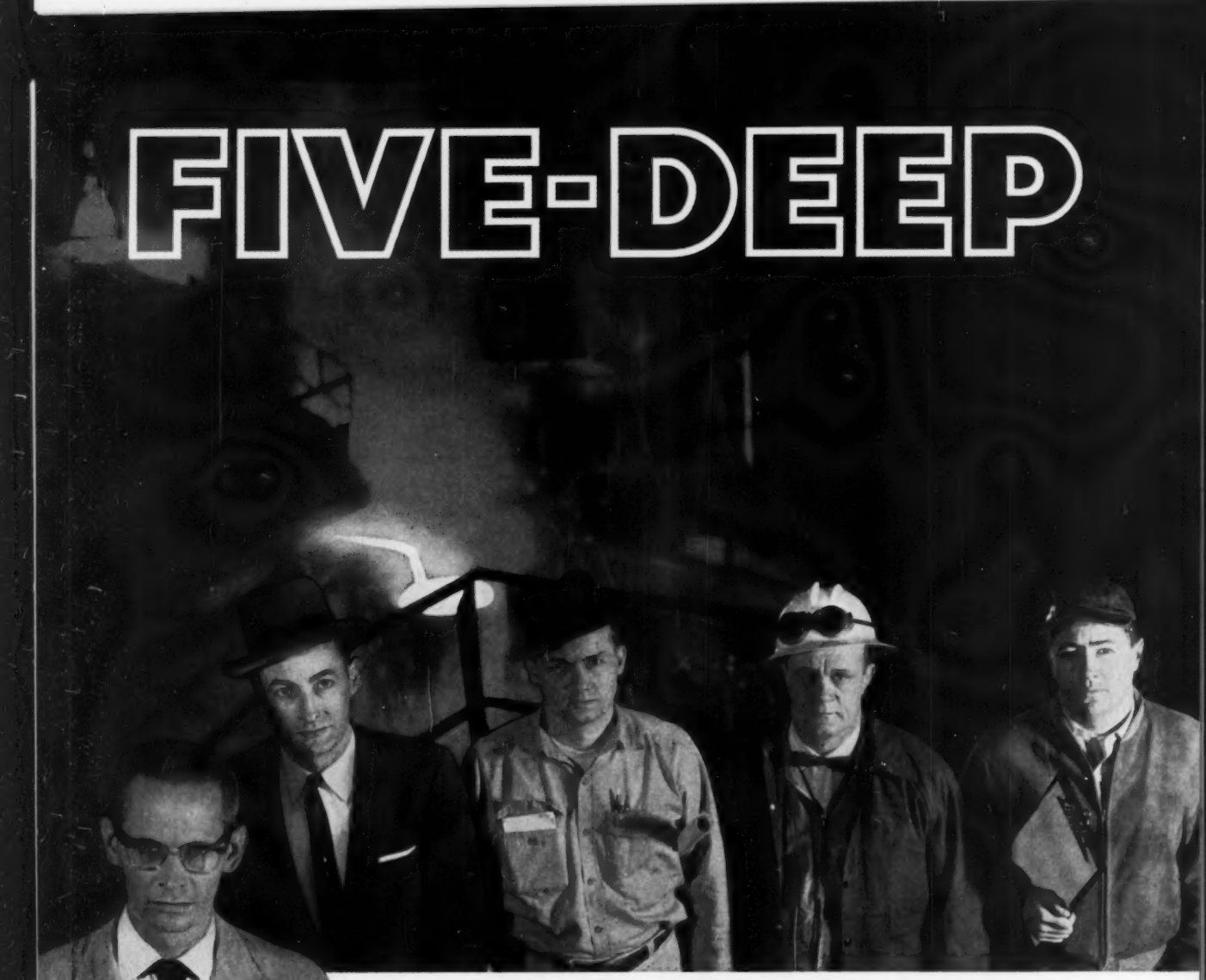
FIVE-DEEP



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1 Technology—many million dollars a year, invested in UCM's 600-man research and development center—helps you produce better, more profitable metals. This is one of the 5 intangible but ever-present extra values of Union Carbide Metals' FIVE-DEEP alloys.

It has brought you more than 100 new alloys and metals designed to give you production economies and improved products. Countless millions have been made and saved because of UCM's research, along with these 4 other extra values:

2 Customer Service brings you our integrated experience in the application of ferroalloys to various melting practices. Engineers from 9 UCM field offices travel a million miles a year to provide on-the-scene assistance.

3 Global Ore Sources assure you uninterrupted supplies of ferroalloys. UCM's close association with world-wide mines provides dependable raw material sources.

4 Unmatched Facilities free you from delivery worries. Only UCM gives you 6 plants—3 with their own power facilities—and 17 warehouses, all located for fast shipments by rail, truck, or water.

5 Strictest Quality Control—with over 100,000 tests per month from mines to shipment—makes sure you always get alloys of uniform size and analysis, with minimum fines, lot after lot.

For better metals, production economies, bigger profits, insist on UCM's FIVE-DEEP alloys. Union Carbide Metals Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y., producer of "Electromet" brand metallurgical products.

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UNION CARBIDE METALS

Only **ELECTROMET** ferroalloys from **UCM** are so deep in extra values to help you.

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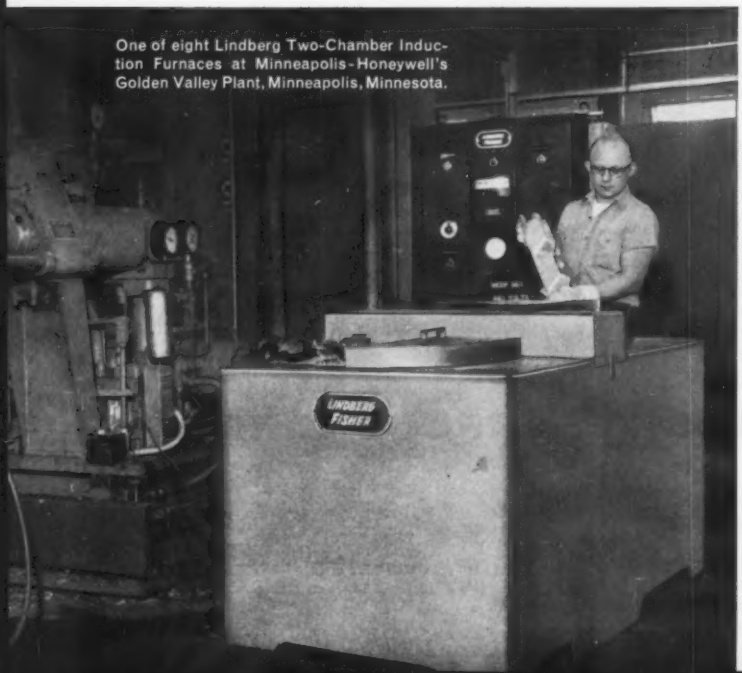
ART GEORGE has a good word to say for Lindberg Melting Furnace performance

QUOTE

Mr. Art George, Senior Production Engineer, Golden Valley Plant, Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.

"Our installation of eight* Lindberg-Fisher Two-Chamber Induction Melting and Holding Furnaces has given remarkable service for more than four years. In this period, with the help of a well executed Honeywell maintenance program, the installation has been unusually trouble-free. Only one of the eight furnaces has required relining over this long period. Handling more than 1,000,000 pounds of aluminum and zinc annually, the installation has unfailingly provided the consistently high quality of metal our precision instruments require."

**Altogether, 44 Lindberg Furnaces are in operation in various Honeywell plants.*



One of eight Lindberg Two-Chamber Induction Furnaces at Minneapolis-Honeywell's Golden Valley Plant, Minneapolis, Minnesota.

These eight Lindberg-Fisher Induction Furnaces melt and hold aluminum and zinc for die casting gas valve housings and other component parts. They are located at the die casting machines where ingot and scrap can be melted and held at the desired casting temperature in one convenient unit. Magnetic fluxing and stirring insures uniform temperatures and consistently clean metal.

In any production process where aluminum needs heat there is Lindberg equipment to apply it most economically and efficiently. Furnaces for melting and holding, casting stations, re-melting or heat treating are available in all capacities, electric or fuel fired. Get in touch with your Lindberg Field Engineer (see your classified phone book) or write us direct. Lindberg-Fisher Division, Lindberg Engineering Company, 2440 West Hubbard St., Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

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heat for industry

BIGGER and BETTER CASTINGS poured with LOUTHAN refractories

Cameron Iron Works in Houston, Texas, which has for the last two years been casting its own forging dies with considerable success, is understandably proud of the 24-ton casting shown in the photograph above.

Poured through Louthan refractory runner tile, the casting is without defect. Note the clean, smooth surface of the gate (circled area of photo at lower left). Here's proof again that Louthan refractories stand up on the job.

Whether you're working in iron or steel, on small parts or huge castings, you'll find Louthan Refractories completely dependable—saving much more than they cost you. Why not try them soon? A complete line of strainer cores, breaker cores and runner tile is available.

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Gray Iron Foundry Milestones—No. 5

THE COLLIAU CUPOLA

ONE of the most significant developments in the history of the Gray Iron Foundry Industry was the invention of the cupola in the early 18th century.

The first cupola was introduced in the United States about 1815, but it wasn't until 1874 that the first prefabricated commercial cupola, the *Colliau*, was manufactured in this country. The Colliau offered several new features including a hot blast, a double row of tuyeres, and other improvements which produced a fast, economical iron melt.

The introduction of the cupola into the foundry marked the point at which foundry operations and steel making went their separate ways . . . and each eventually became a vital factor in the American economy.

As a supplier of quality foundry coke and pig iron, Pittsburgh Coke & Chemical Company is proud to contribute to the continuing growth of the great Gray Iron Foundry Industry.

Reproductions of the "The Colliau Cupola," suitable for framing, may be obtained without charge by writing to the Coke & Iron Division, Pittsburgh Coke & Chemical Company, Grant Building, Pittsburgh 19, Pa.

COKE & IRON DIVISION
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Neville Pig Iron and Neville Coke for the Foundry Trade 1840

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A relatively new cast engineering material is serving a multitude of applications in the automotive and related industries. Additions of high-powered boron and bismuth have created new parameters for product performance. Pearlitic malleable is now being used for crankshafts, pistons, gears, yokes. This special report to the Institute of British Foundrymen on progress in the United States tells how . . .

Pearlitic Malleable Iron Meets New Industry Demands

by CARL F. JOSEPH
Technical Director
Central Foundry Division, GMC
Saginaw, Mich.

THE GROWTH of pearlitic malleable iron usage in the United States has been confined to a relatively short period. In 1938, approximately 300 tons was consumed by the automotive industry. Today, total production of pearlitic malleable iron exceeds 200,000 tons annually.

Growth of its use during World War II was tremendous. Pearlitic malleable parts were given every known endurance test for many military applications. Before the war ended, General Motors Corp. was producing 25 different pearlitic malleable castings for the 0.50 caliber machine gun, and 12 others for the 0.30 caliber, replacing many high quality steel stampings and forgings. Pearlitic malleable parts were also produced for the 0.30 caliber rifles and carbines used by the United States Armed Forces. Over 20-million gun parts were produced in pearlitic malleable iron during the war period.

The continuing rapid growth in acceptance and use of pearlitic malleable iron is largely due to the fact that producers are stressing uniformity and are giving the customers casting properties necessary for satisfactory performance. Table 1 illustrates the annual shipments of pearlitic malleable iron castings, in tons, during the last thirteen years.

1. Pearlitic malleable iron production has had phenomenal growth to an annual level of 200,000 tons.

Note that during the year 1959 approximately 200,000 tons of pearlitic malleable iron was produced by the member companies of

Continued on page 39

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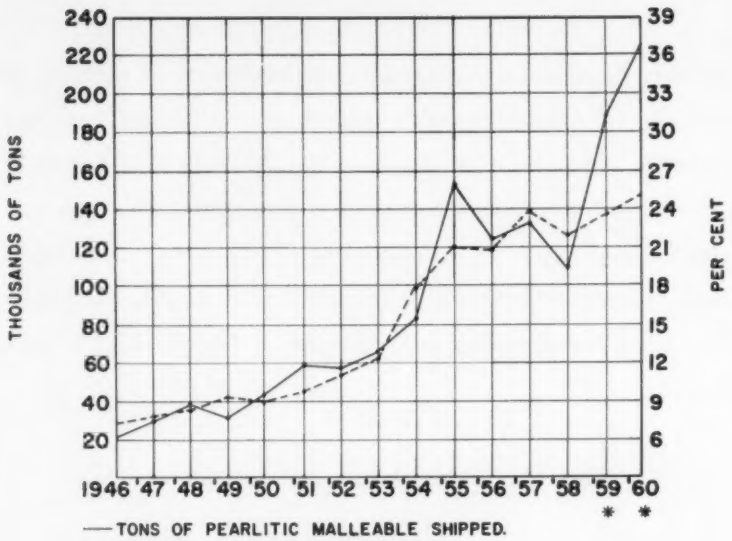
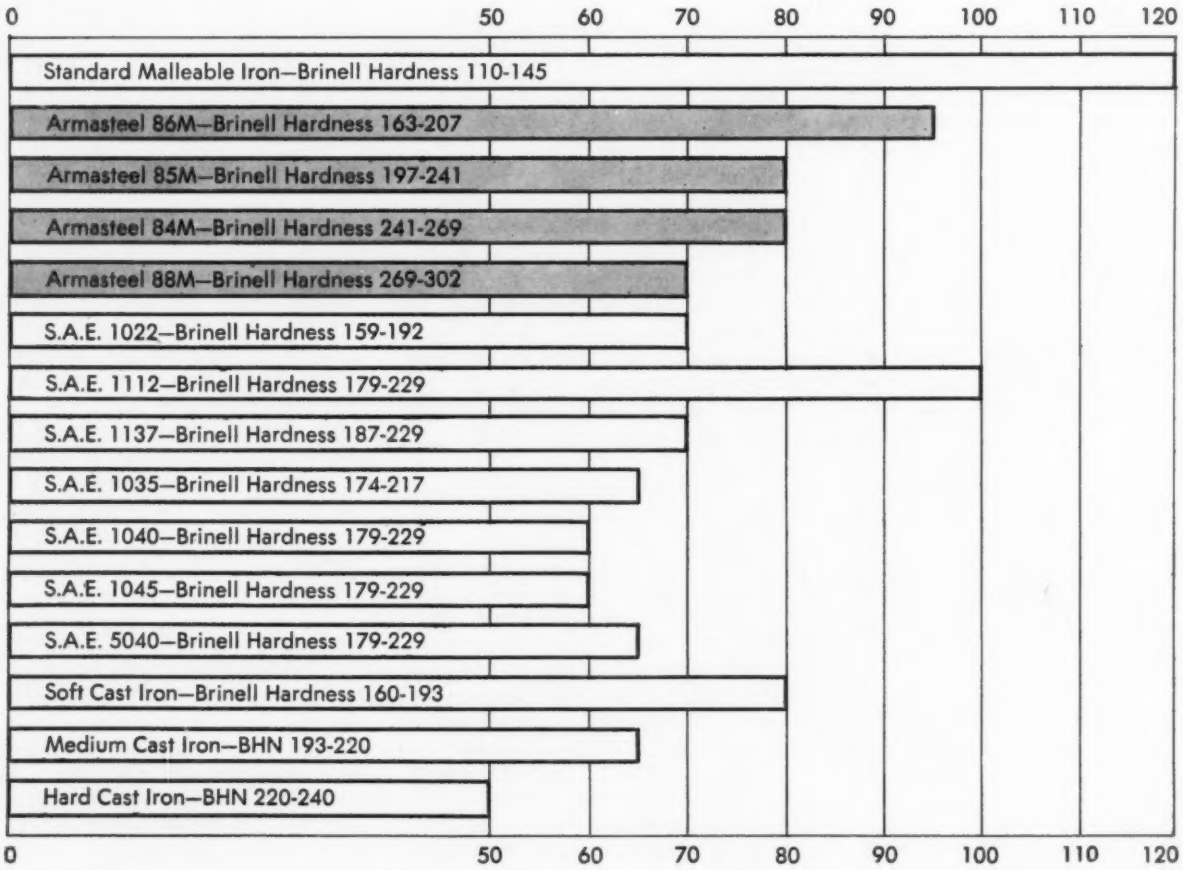
SHIPMENTS OF PEARLITIC MALLEABLE CASTINGS



—— TONS OF PEARLITIC MALLEABLE SHIPPED.
--- PER CENT OF TOTAL SHIPMENT OF MALLEABLE CASTINGS SHIPPED.
* ESTIMATED.
THE ABOVE INFORMATION WAS SUPPLIED BY THE MALLEABLE FOUNDERS' SOCIETY AND REFERS TO TONNAGE OF THEIR MEMBERS ONLY.

TABLE 1

MACHINABILITY RATING (Per cent) — Figure 1



Properties and Applications of Various Types of Pearlitic Malleable Now Produced at Central Foundry

ArmaSteel Grade	Tensile Strength	Yield Strength	Elongation in 2 in.	Brinell Hardness	Impression 3000 kg.	Applications
GM86M	70,000 psi.	48,000 psi.	5.0%	163-207	4.2-4.7 mm.	For less highly stressed parts, such as C-clamps, auto front wheel hubs, diesel engine brackets, levers, transmission cases.
GM85M	80,000	60,000	3.0	197-241	3.9-4.3	For moderate strength parts. Used for diesel pistons, differential axle cases, rocker arms, and transmission clutch hubs.
GM84M	100,000	80,000	2.0	241-269	3.7-3.9	For high-strength applications, such as transmission gears and universal joints. Parts are oil quenched and tempered at foundry.
GM88M	105,000	85,000	2.0	269-302	3.5-3.7	Strength characteristics similar to alloy steel forgings. Good wear resistance and high yield strength in as-machined state. Used for universal joint yoke, idle and balancer gears, planet gear carrier.

TABLE 2

Continued from page 37

the Malleable Founders' Society. This represents about 24 per cent of the total malleable iron tonnage.

The Council of Iron Foundry Association in England reports a total shipment of malleable iron castings equal to 161,000 long tons in 1958. Of this, 14,000 long tons were pearlitic malleable iron—less than 10 per cent of the total malleable iron production.

The production of pearlitic malleable iron generally starts with the same base metal as that used for making malleable iron. The melting processes and raw materials used vary widely, depending somewhat on the geographical location of the plant. By far the larger percentage of the tonnage produced in the malleable iron industry is melted by the duplex process. The cupola is used as the primary melting furnace. Molten iron is then transferred to a mixing or holding furnace, either an air furnace of the reverberatory type or an electric arc furnace.

Close chemical control of carbon, silicon, and manganese is exercised. The range of these elements depends on the type of melting equipment used and the metal charge makeup of the raw materials. For cupola-air furnace duplexing, chemical analysis may be 2.35-2.50% C, 1.00-1.25% Si, 0.38-0.45 Mn, less than 0.20 S, and less than 0.10 P. Elements such as copper, manganese, or molybdenum are sometimes added to the molten metal, either in the melting or holding furnace or as a ladle addition.

2. Bismuth additions permit casting heavier sections and boron improves annealability.

In recent years, much thought has been given to the production of heavier thickness castings. The mottling tendency of the white iron prohibits many malleable iron foundrymen from pouring castings in excess of 2-inch sections. Adding small amounts of bismuth has helped to solve this problem to some extent. Central Foundry Division of GMC uses bismuth in amounts of 0.005 to 0.025 per cent, depending on the cooling rate of

the casting in the mold. Bismuth is added to the ladle, just prior to pouring, and has an effective ladle life of about eight minutes. The addition of bismuth to malleable iron for preventing mottling is covered in General Motors patent No. 2,370,225.

The use of boron in malleable iron melting practice dates back almost thirty years. For many years, boron was used in amounts of 0.0010-0.0015 per cent to counteract any bad effects of chromium in the iron. Chromium in excess of 0.03 per cent in malleable iron is usually considered harmful. However, with chromium as high as 0.10 per cent and boron at 0.0025-0.0035 per cent, good pearlitic malleable iron can be produced.

Many malleable iron foundries operate at this boron level and add it in their cupola charge raw material—either in the pig iron or ferrosilicon. Ferroboron additions to the molten iron are also made. Boron improves the annealability of both ferritic and pearlitic malleable iron and reduces the time of second stage graphitization of the ferritic.

Much of the pearlitic malleable iron is heat treated in atmosphere-controlled, radiant tube furnaces. They are 120 feet long by 18 feet wide and are as gastight as possible. Surface condition on a pearlitic malleable iron casting affects the machinability and the mechanical properties. Surface decarburization is controlled by maintaining a high nitrogen atmosphere in the furnace with neutralene gas —a commercially prepared nitrogen.

The malleablizing temperature of 1750 F. is maintained about 8 hours to break down the massive carbide in the as-cast structure. The castings are cooled to around 1650 F. and quenched as rapidly as possible in air. This is followed by a tempering treatment or an oil quench and temper, depending on the mechanical properties and hardness required.

Pearlitic Malleable Meets Many Engineering Requirements

Superior machining qualities, excellent yield strength, and resistance to severe service conditions contribute to the metal's increasing popularity with designers.

Indicative of the broad range of properties obtained in pearlitic malleable irons are the specifications of the American Society for Testing Materials: Specification A220-55T.

3. Different pearlitic types meet a variety of engineering requirements.

Table 2 shows the properties and applications of various types of General Motors pearlitic malleable. GM 85 M and GM 86 M are air quenched and tempered and used for less critically stressed parts. GM 84 M is specified for high strength applications and is produced as an oil quench and tempered part. GM 88 M is used where castings require exceptional good wear and strength characteristics. It is usually machined and used as received from the foundry; whereas some of the other types are quite often heat treated by the customer after machining.

4. Superior machinability contributes big savings to over-all cost of finished parts.

One of the most valuable advantages of pearlitic malleable iron, —compared to steel forgings of the same Brinell hardness—is the machining cost reductions which range from 10 to 30 per cent. This property leads to tremendous savings on any part requiring considerable machining. In many cases, the machining cost of a casting is from 2 to 5 times the cost of the rough casting. This definitely adds to the ultimate cost of the product.

Figure 1 illustrates comparable machinability. Machinability is an arbitrary measure of the relative ease of cutting a metal. The standard of comparison is a free cutting grade of screw stock machine steel, which forms a base line of 100 per cent.

One of the major factors in machinability is the microstructure. Oil quenched and tempered pearlitic malleable iron with a spherio-

dized cementite matrix has better machinability at the same hardness than a casting produced with a pearlitic matrix. An improvement of approximately 18 per cent in favor of the oil quenched product over the air quenched material is obtained in broaching, milling, and turning of pearlitic malleable iron.

Another valuable property of our pearlitic malleable is its ability to respond to localized hardening by either flame hardening or induction hardening. Tests on numerous automotive parts indicate a minimum of 50 Rockwell "C" will produce a satisfactory wear hardness. Selectively hardened parts eliminate many of the costly heat treatments, such as carburizing or carbonitriding, on rocker arms, crankshaft sprockets, gears, and similar parts. Examples are shown in illustrations (right).

Hardenability measures the extent of hardness penetration toward the center of a steel or iron part when heat treated. Pearlitic malleable iron has a hardenability about equal to that of low alloy steels. It is suitable for full hardening up to ½-inch diameter when oil quenched.

5. Selective hardening assures good wear resistance of gears, pistons, and sprockets.

Such parts as automatic transmission gears and transmission pistons (right), cast of our pearlitic malleable iron, will resist wear and give long and useful service under heavy loads at high speeds. Such performance is attributed to the high controlled hardness of the matrix in which imbedded temper carbon nodules retain and store lubricant.

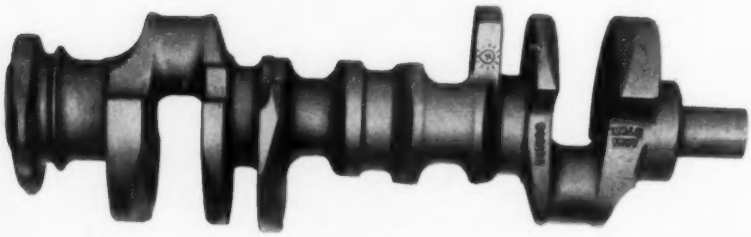
Castings receiving increasing attention from automotive engineers are those of the high yield strength type. High yield strength together with good machinability is a rare

Automotive Rocker Arm

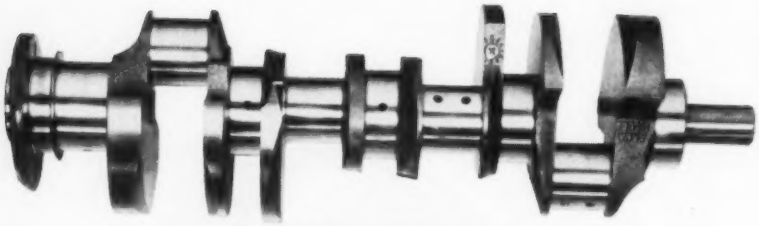
Crankshaft Sprocket

Transmission Gear

Transmission Piston



Armasteel Casting
Weight 85.4 Pounds



Machined Armasteel Crankshaft
Weight 68.8 Pounds

combination offered by pearlitic malleable iron.

The universal joint yoke is a good example of this type of casting, replacing an SAE 1145 steel forging. This part is produced as an SAE 80002 pearlitic malleable iron part and has many of the advantages of a casting, both in design and machinability.

6. Recent research results show pearlitic malleable has excellent properties in the temperature range of 800-1200 F.

Recent research on both malleable iron and pearlitic malleable irons at Purdue University has indicated excellent physical and mechanical properties at temperatures up to 1200 F. Test bars have withstood maximum stress at elevated temperatures for as long as 2300 hours. This points the way to many new applications where pearlitic malleable iron can be used at high temperatures. The data obtained at Purdue indicates a high stress level versus rupture time, equal to or superior to other ferritic cast materials, particularly at 800 F. The values obtained for pearlitic malleable irons compare favorably with those published for molybdenum-alloyed irons.

7. Pearlitic malleable is now meeting the severe service requirements of diesel engine pistons, automotive crankshafts, and truck suspensions.

At upper right is a diesel engine piston produced in our GM 85 M pearlitic malleable. In truck and bus operations, these pistons are inspected at approximately 300,000 miles. Some pistons will last the life of the engine—usually in excess of one-million miles. In road building equipment, some customers replace pistons at about 6000 hours, regardless of their condition. The pistons operate between 500-750 F. depending on load and speed.

Another pearlitic malleable iron part which has come into favor in recent years is the automotive crankshaft. The four major considerations which favor the cast crankshaft over the steel forging are:

(a) Excellent machining characteristics.

(b) Closer dimensional tolerances.

(c) Improved design flexibility.

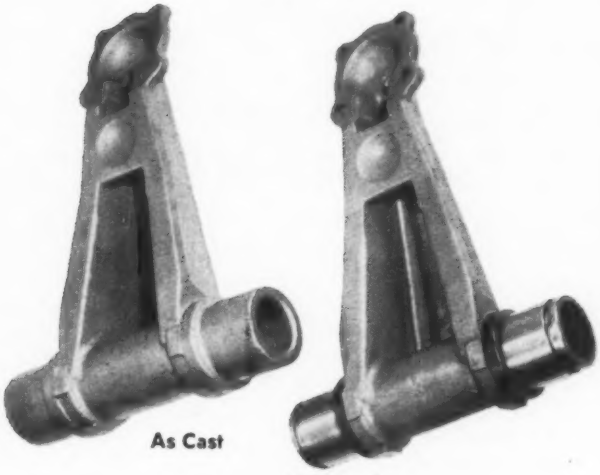
(d) A lower cost material.

A popular V-eight pearlitic malleable iron crankshaft both as-cast and machined is shown at top of page. Over one million of these crankshafts have been produced and performance has excelled in every respect.

Another application of a critical service casting for our pearlitic malleable is the upper control arm on the front suspension system of a truck (upper right center). Two of these castings carry the entire weight of the front end.

Diesel Piston

Upper Control Arm



As Cast

Machined

Pearlitic Malleable Has Variety of Applications

Wide range of mechanical properties constantly increased by foundry research, add to new uses.

Industry is now demanding a higher hardness product with fair machining characteristics. The new material GM 88 M is oil quenched and tempered to a Brinell specification of 269-302. No further heat treatment is required. This material combines exceptional wear resistance with fair machinability in a cast part. The customer is relieved of heat treatment facilities and capital expenditures. Where distortion during heat treating is a problem, this new material has many advantages. One widely used part is the planet gear carrier for an automatic transmission. This gear was formerly an alloy steel forging. Another manufacturer is using this type of material for a universal joint yoke; another, in idler and balancer gears on a Diesel engine. This was formerly a carburized and hardened steel part.

There are many other good properties of pearlitic malleable iron, among which are excellent nonseizing properties, mirror-like surface finishes, and good dampening characteristics.

8. Malleable parts can be easily formed and shaped by punching, coining, rolling, and spinning.

Ferritic and pearlitic malleable iron castings are amenable to special forming and shaping operations:

(a) Punching and Coining—Punching holes is common practice on hinges, seat brackets, and spring clip pads. This eliminates a drill operation. The thickness of the punched hole is usually limited to its diameter. Longitudinal slots can also be punched.

Coining of castings can either be done by the producer or by the casting user. Where coining tolerances are acceptable, substantial savings can be made over machining. Present coining operations include such parts as idler arms, rocker arms, anchor supports, and spring hangers.

(b) Oil Groove Rolling—Commercial application of rolling an oil groove in a crankshaft for a refrigerator compressor, for example, is more economical to roll the groove than to machine it.

(c) Spline Rolling—Spline rolling of pearlitic malleable iron of

various hardness ranges has been successfully accomplished. Both splines and threads have been rolled on a crankshaft for a small compressor.

(d) Spinning—We are currently furnishing universal joint yokes on which the ends are crimped or spun over a steel enclosure. This spinning operation of closing in at the ends might have considerable promise on the other applications, such as the ball joint housing for an automobile front suspension system.

9. Quality castings require strict quality control in every operation.

Quality is never an accident, but a result of high intentions, genuine effort, intelligent direction, and skillful execution. *Quality is built into the casting in every operation.*

There follows a description of some of the unusual inspection methods and specially designed equipment used to improve and measure the quality of our castings.

Radiography—With the advent of Cobalt-60 radiography, a vast new area of casting inspection was opened and the atomic age was brought to our plants. We use Cobalt-60 radiography as another means of non-destructive testing to detect the presence or absence of defects in castings.

Sonic Testing—As more and more castings replace forgings on highly stressed critical applications, new and faster methods must be devised to check the *internal* as well as the *external* soundness of *every* casting to insure the customer defect-free, high-quality parts.

The *Sonic Tester*, developed by General Motors Research and our engineers, is a non-destructive device which will check the internal structure of a casting as well as its surface. This method is used extensively in our plants on such parts as *slip yokes, brake* and *clutch pedals*, and *crankshafts*.

The procedure for testing sonically is to set the casting into vibration by some mechanical or electrical means and pick up and record the frequency of the vibration. This inspection technique is based on the fact that if the castings are identical or nearly so, the frequency at which they vibrate will be within a definite range. If defective, the casting will vibrate at some totally different frequency. We are using this control on a number of our castings.

This method uses certain properties of high frequency ultrasonic energy. Sound waves of frequencies above the hearing range of the human ear are beamed to travel through a casting in a straight line. If they encounter a defect in the metal, the sound waves are bent or dispersed, thus detecting a hidden flaw. To date, this method has only been used in production on the automotive crankshaft.

Quantometer—Rapid determination of silicon, manganese, boron, nickel, chromium, and molybdenum are accomplished by arcing two electrodes cast from the molten metal and reading the spectrum on a direct reading spectrograph called a quantometer. By means of this instrument, a chemical analysis of this electrode is made in less than one minute.

The sciences of electronics and atomic energy have become highly useful in our foundry. We feel that each step in our inspection program is necessary to give the customer the highest quality castings possible. The most important item we have to sell is *quality*.

Conclusion

Malleable iron foundries are continuing their research and development work on new materials. Experiments with an "as cast" pearlitic malleable iron are being watched with considerable interest and can be expected to develop into a commercial material.

Pearlitic malleable iron is truly a versatile material. Its mechanical properties cover a wide range of applications in all branches of engineering and manufacturing. Many conversions from steel forgings, stampings and weldments have been and are constantly being made at a considerable savings per part. The tremendous growth in the use of pearlitic malleable iron during the last 20 years is an indication of its acceptance by industry as a reliable engineering material.

Note: Space limitations required condensing parts of this AFS officially sponsored paper to the 1960 Annual Conference of the Institute of British Foundrymen.

Truck-Trailer Makers Offer Foundrymen Dynamic Market

Production innovation and competitive price hold key to new profits for metalcasters. If castings are to increase their share-of-market status, foundries must learn to apply their capabilities to meet changing needs.

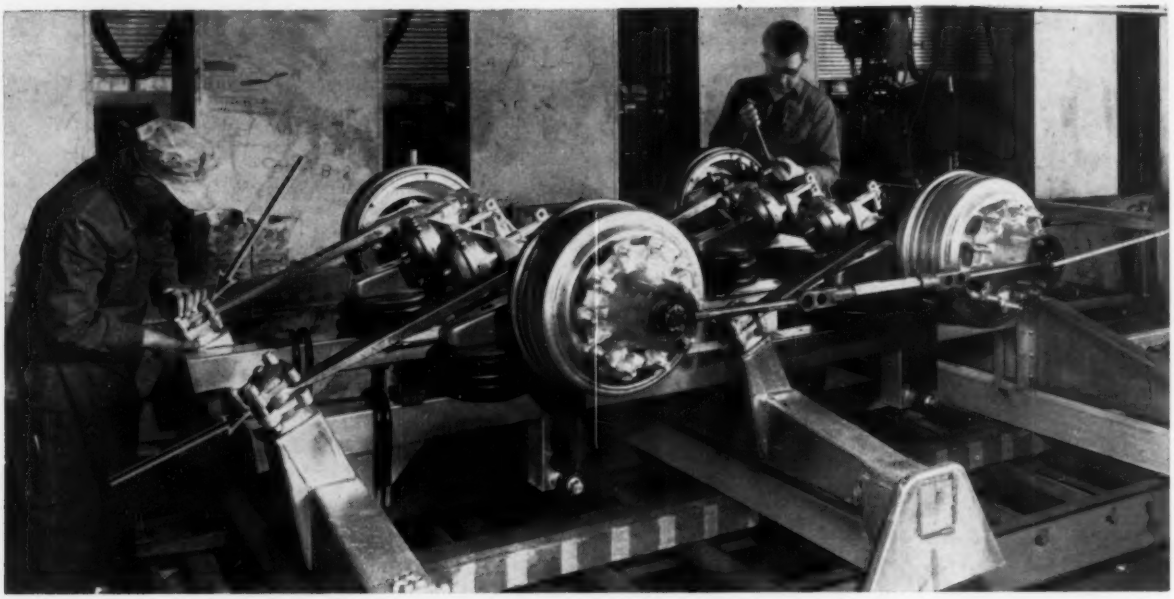
by JACK H. SCHAUM, Editor

By 1965, some 54,000 *more* truck trailers will be on the nation's highways. Add to this a steady replacement factor for 800,000 commercial trailers already on the roads, and you find a new growth industry of significance.

To those of us in metalcasting, particularly those seeking new or diversified markets, this means:

1. Greater profit opportunities.
2. A challenge for product improvement and product innovation.
3. A chance to recapture business lost to competitors outside the metalcasting industry.

How can this be done? Experts in the truck trailer industry are providing the clues in this special survey by MODERN CASTINGS. (See "The Fifth Wheel," a story of a metalcastings breakthrough on page 48.) As reported by leading trailer manufacturers, cast parts on truck trailers are made of steel, gray iron, malleable iron, ductile iron, and aluminum. But to provide such castings is not enough. Full cognizance



must be taken of important trends in the industry.

- Larger trucks handling heavier loads faster.
- Weight reduction through use of lighter weight materials in the truck trailer itself. Bigger payloads result.
- The cost of components which go into the manufacture of truck trailers. All other things being equal price governs the selection between castings and competitive fabrications. *This will continue to be a key purchasing factor.*

What does this mean to metalcasters? Makers of truck trailers provide some specific answers.

"We could use more steel and ductile iron castings if we could get thinner sections with closer control on thickness without having to pay prohibitive prices for this control. Recent price increases in steel castings have forced us to go back to fabrications in some parts where it was feasible to fabricate."—N. M. Norman, vice president—engineering, Dorsey Trailers.

"If we had better dimensional control, lower costs, and higher physical properties I think that we could use more cast parts."—W. R. Hummel, chief engineer, Trailmobile, Inc.

Use More Pearlitic Malleable Iron

"At the present time, we are using both carbon and alloy steel castings; also straight carbon and alloy gray iron castings, and aluminum alloy castings. The elimination of shrinks and voids in these materials would be most desirable . . . We are finding increased use of such materials as pearlitic malleable iron. In some cases this is replacing steel forgings."—James Sorenson, chief metallurgist, FWD Corp.

(*Note*: See article on pearlitic malleable iron revelopments on page 37, this issue.)

"A reduction in cost would be the biggest single factor in causing us to use additional castings. Another which might be considered is a reduction of cost of pattern equipment. This would allow us to consider castings rather than steel fabrications for small quantities of parts."—Charles L. Small, chief engineer, Hendrickson Mfg. Co.

"Higher *endurance* and strength at lower cost, improved quality to reduce porosity and holes in castings, thinner sections, and price would cause us to use more castings."—George Chieger, assistant director of engineering; R. G. Flagan, director of research and engineering Fruehauf Trailer Co.

Casters Can Build Business

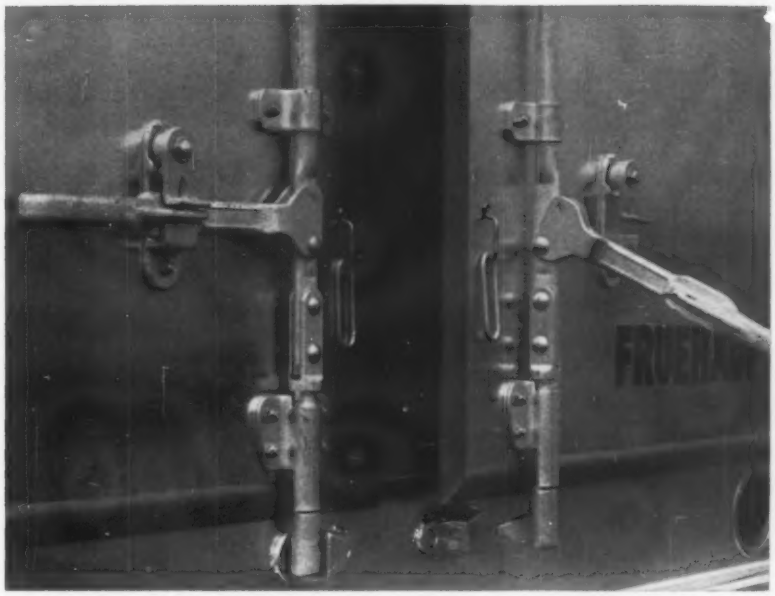
The substance of these comments, and those of other experts in the truck trailer field, is that *foundrymen can get a still better share of truck trailer fabricating dollars.* These dollars will go to those who can:

1. Cast thinner sections.
2. Reduce internal castings defects.
3. Raise casting endurance and strength.
4. Cut pattern costs.
5. Control dimensions more accurately.
6. Meet price competition from those outside the metalcasting industry.

The product posibilities are many. As reported by leading manufacturers, cast parts on trailers include:

spring hangers	corner bumpers
radius rods	platform corners
seats	vertical support housings
landing gears	axle brackets
door hardware	spoke wheels
wheels	brake drum liners
suspensions	tandem axle suspension parts
rear corners	leg supports
roof corners	hose couplings
king pin mountings	spring mounting brackets

Fruehauf Trailer Co. uses the castings pictured in this article. Photo on first page shows inspection of cast steel spoke wheels. On left, workers are assembling cast mounting brackets for trailer leaf springs.



This view of rear door on trailer truck shows how steel castings are used for handles, handle locks, cam ends, and cam locks.

It is worthwhile for foundrymen to compete in the trucker trailer industry, particularly when price is such an important factor? Indications are that it is. A special study (by Marvin J. Barloon, Western Reserve University, for the Truck Trailer Manufacturers Assoc.) forecasts that the freight hauling capacity of truck trailers will increase some 100 per cent by 1980. There will then be 1,200,000 trailers moving more than 400 billion ton-miles.

Supporting this forecast are:

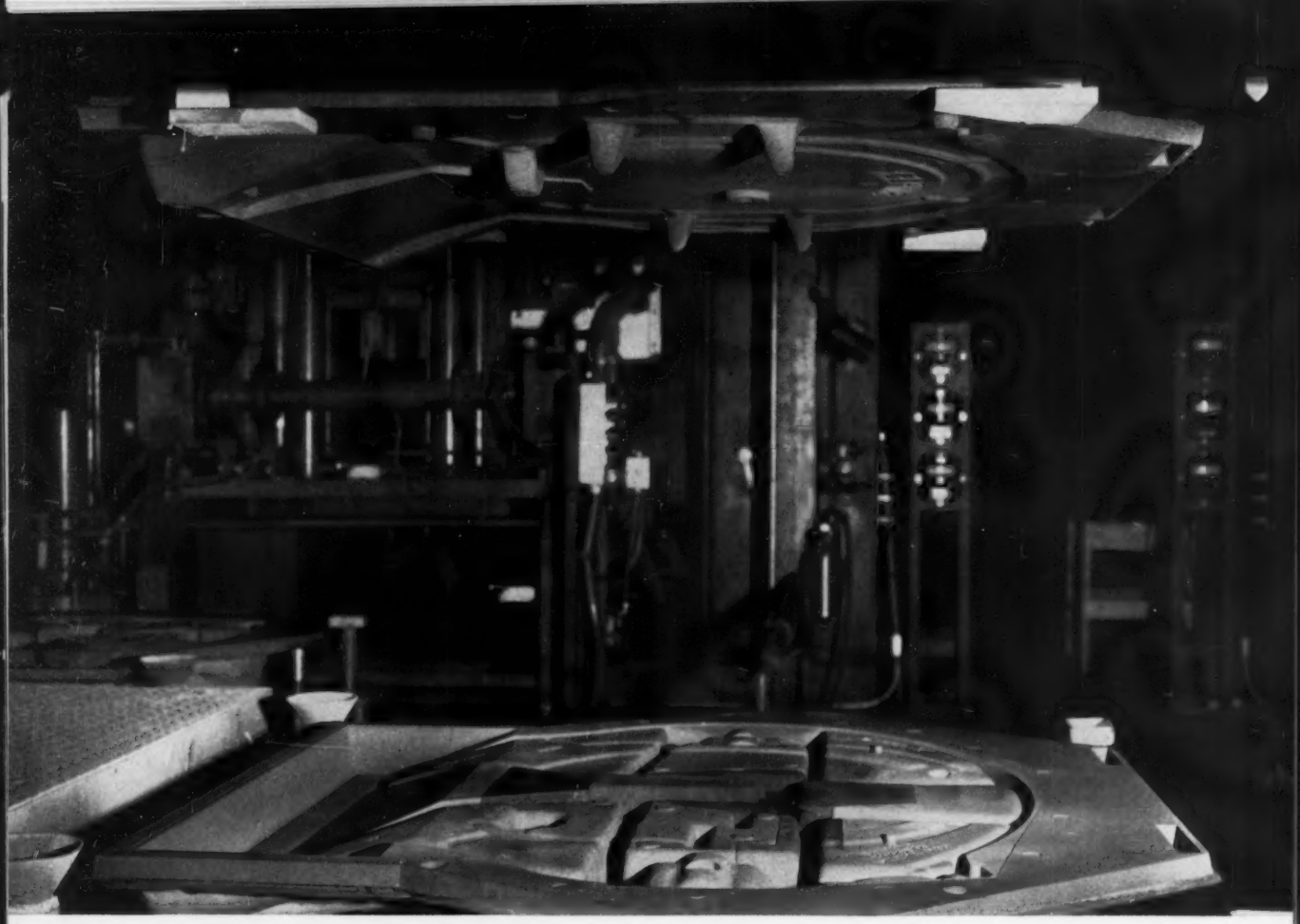
- The development of new interstate highway systems. This provides more opportunity for truck trailers to serve industries and people with fast transportation.
- The increased popularity of piggyback and fishyback demountable vans on long hauls by railroads and ships. Here is product variation, requiring additional components for the finished product.
- The growing tendency of businesses and industries to operate with smaller inventories. This calls for changes and speed-up in product distribution.
- The suburbanization of populations and industry. This creates new needs for trailers in the delivery of products of all types.

Conclusions

Such basic trends indicate that the changes in truck trailer manufacture are important and far-reaching. And it means that foundrymen have an opportunity to serve a growing, dynamic industry as never before. It's definitely a chance to recapture, in part, tonnage lost through declining markets in other fields.

An alert foundry management always looks afield for new ideas in processing, in materials, in methods, and for sales. It never gives up this search.

Looking underneath a trailer-truck you can see the cast upper housings which are a part of the square leg supports. Legs are part of "landing-gear" mechanism that supports trailer when detached from truck.



COVER STORY

"The Fifth Wheel"—A Casting Breakthrough!

THE SUCCESS STORY of American Steel Foundries' bold imaginative modernization step at their Indiana Harbor Plant is a particularly appropriate demonstration of creating new market opportunities in the truck trailer industry.

ASF management made an exhaustive study and concluded they could be more competitive by converting this plant completely to the zircon sand shell molding process. The installation was dedicated to producing higher quality steel castings at lower over-all cost to the customer. One of the first new product breakthroughs came in the form of successfully casting the Fifth Wheel—pictured on this month's MODERN CASTINGS cover.

The Fifth Wheel is the vital connecting link between automotive highway tractors and load carrying trailers. Zircon shell molds have added new parameters to the steel casting process by making it possible to cast large castings requiring less weld repair and cleaning operations than ever possible to achieve in green sand molds. Most of the machining was also eliminated.

To convert this new concept of steel foundry operations into actuality, ASF completely remodeled their Indiana Harbor plant. The largest shell molding machines ever built in this country were designed for a maximum of mechanization and automation. Shells for the Fifth Wheel measure 44 x 55 inches. Steel brake beams for railroad cars are cast in 26 x 80 inch shells. Other castings made in the modernized foundry are sprockets, industrial valves, and power shovel tooth points.

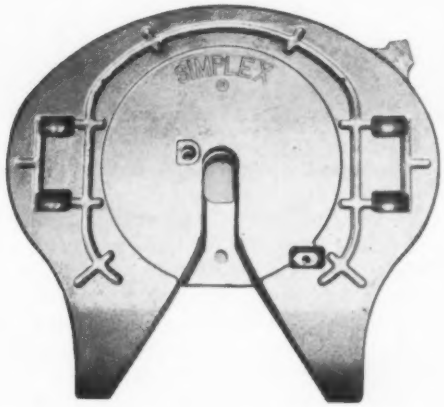
The sand system uses zircon exclusively—400 tons in all. About 70 tons is coated with phenolic resin per day. Because of its expense, $70 per ton, the zircon is run through a reclaiming system which burns off carbon at 1800 F. After cooling, the sand is warm coated with resin at 170 F in one ton batches.

Low alloy steel is melted in basic arc furnaces. The as-cast weight of the Fifth Wheel is 320 pounds. Simplified gating which permits pouring through risers results in improved yield over previous practices. Resulting castings are very clean and free of defects. As a consequence, weld repairing and cleaning operations have been cut drastically. Thin carburized skin on castings is scaled off by heat treating in oxidizing atmosphere.

The shell molded Fifth Wheel is cast so close to size that it requires virtually no machining. Seven sets of holes are accurately cast-in instead of being drilled. All this adds up to engineered castings that are better than weldments and forgings.

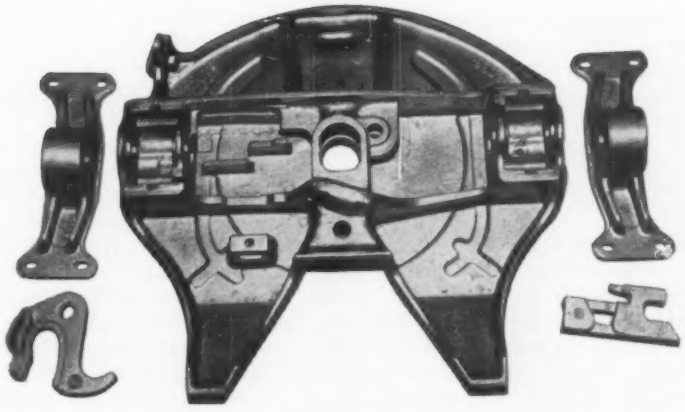
1 Picture on the left shows the cope and drag halves of zircon shell mold in position for closing. Extreme accuracy permits many holes to be cast, and much of the machining formerly required has been eliminated.

2 Molten steel flows from bottom-pour ladle into zircon shell mold to form fifth-wheel. Special clamps hold two mold halves together against hydrostatic pressure of metal. Refractory zircon resists high temperature, gives excellent finish.



3 Top view of the as-cast steel fifth-wheel demonstrates the intricate detail and fine finishes achieved with new process.

4 Bottom view of fifth-wheel reveals more of the fine detail which can now be cast into the unit. On either side are additional cast components used in the final assembly.



Contest Promotes Castings in Product Designs

Seeing the need for broadening the castings market, Foundry Department management at General Electric turned to their design engineers, value analysts and other company employees for aid. The contest, an industry-first, produced the desired results . . . renewed interest in castings. It can well serve as a model for other firms.

by GLENN J. COOK
Manager-Marketing
Foundry Department
General Electric Co.

FOUNDRIES at General Electric Co. have had to run hard just to keep up with the technological progress of other departments and with competing technologies.

Just as exhausted track stars either fall by the wayside or get their second wind when the pace becomes faster and the competition more keen, the foundry department did not falter. Instead it picked up its heels and began a vigorous promotion of cast products. The net result was an annual saving of $217,000, considerably more new castings business and a renewed interest in, and appreciation for, castings.

Taking the form of a contest, the idea was generated by management of the foundry department, and became known as the "Convert to Castings Contest." From its inception, the contest was conceived as only one element of an intensive campaign to encourage design engineers, value analysts, manufacturing engineers, and others to consider using castings in their product designs.

Results Gratifying

The results from the contest have been very gratifying. Annual savings to Company businesses were $217,000. These were the savings on only the entries which met all the exacting tests prescribed. All savings were carefully validated by the individual departments in which the castings are used. Currently, no accurate figures have been compiled as to the added castings business generated by the campaign. We expect, however, the ultimate effect will be several times that of the reported savings. Parts, similar to those entered in the contest, are now being routinely designed as castings because of the successful conversions. *In fact, one major new line of castings is expected to grow out of one of the conversions.*

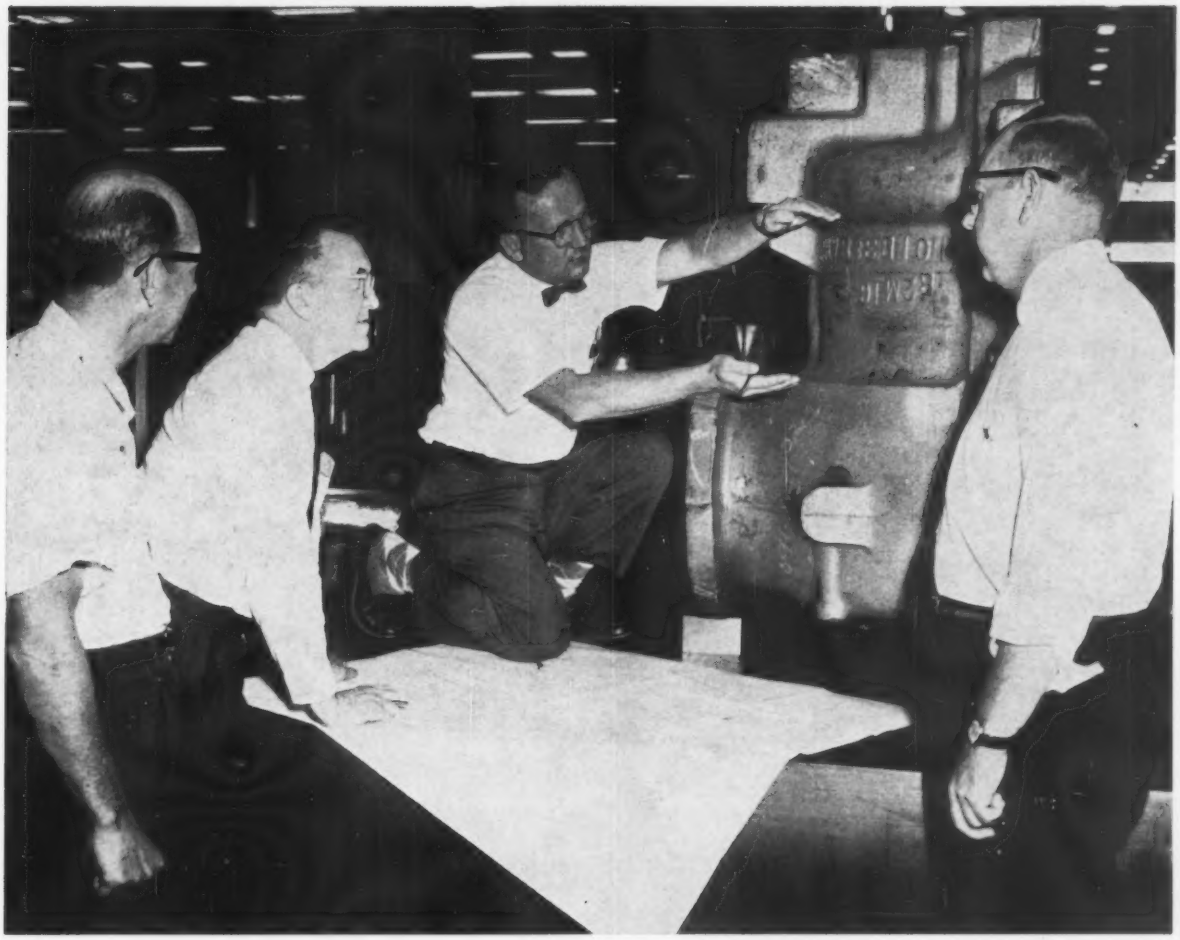
Perhaps an even more significant result has been the change in attitude of many engineers as a result of the intensive campaign of information, personal consultation on design problems, and the special incentive for taking a new look at opportunities castings use offers. The campaign gave the foundries many opportunities to bring engineers up-to-date with new developments in castings.

Consequently, there is increased recognition for castings as useful and versatile engineering materials. Consistent emphasis of the "engineered castings" theme is a big contributing factor.

The contest was planned as an internal General Electric campaign only. Part of the strategy was to reach beyond the present major castings users and try to stimulate thinking of castings in product groups where historically few castings had been used. In a company which employs over 20,000 engineers, this represented an ambitious undertaking.

The elements of the campaign as planned comprised:

1. An intensive direct mail promotion directed to



The winning team in the Convert to Castings contest was from the Small Steam Turbine Dept. The members suggested that steel wheel casings be cast instead of fabricated. Annual saving is estimated at $48,597.

more than 4000 key engineers, value analysts, managers, purchasing people, and others in a position to influence the use of castings.

2. A contest to provide special incentives of monetary and recognition awards.

3. Personal selling and assistance with applications from foundry sales personnel, casting design engineers, and others.

On this latter point, the Foundry Department had provided for many years design assistance, metallurgical counsel, and other help in applying castings. This service is provided through the sales people and by several full-time castings design engineers who work directly with engineers in the principal user departments. The service has proven itself useful and has been well accepted in the product departments where the use of castings has been greater. Therefore, one of the objectives of the campaign was to extend this acceptance into other areas. Thus, all contest publicity tied-in the offer to help contestants with their applications. Also the sales representatives were urged to participate personally in promoting the contest in the areas where they were calling.

The Contest

The first question faced was, "What do we want to encourage?" Should the awards be based on:

1. New castings business obtained by the Foundry Department?

2. New castings business generated regardless of whether it is produced in Foundry Department facilities?

3. Cost reductions to the department in which the castings are used?

The latter basis was chosen for these reasons:

1. The customer departments could be expected to support the program with enthusiasm only if the customer benefits were kept primary.

2. Well established procedures were already in place in all departments for evaluating and validating cost improvements. Thus, an accepted, ready-made, completely objective system for judging was available for use in the contest.

3. We were satisfied that if a cost reduction oppor-

CONVERT TO CASTINGS CONTEST RULES

1. Contest runs from March 31, 1959 through August 31, 1959. No entries will be accepted after contest closing date.
2. The casting cost reduction must bear Engineering and Manufacturing approval of your Department and is to be certified by your Department Manager-Finance.
3. The Manager-Finance of the Foundry Department will be the final judge, based on the certified cost reductions submitted.
4. Contestants may be individual employees or a group of employees, except for Foundry Department employees, employees eligible for awards under the General Electric Suggestion System and employees holding a position level of 15 or above.
5. Cost reduction must be based on an official casting quotation from the Foundry Department. Foundry Department personnel will be available to supply design and application assistance.
6. Cost reduction must cover estimated requirements on the basis of one year's production.
7. Additional copies of contest rules and entry forms can be obtained.

tunity could be proven and validated under existing procedures, we could get the application completed and the work into one of our foundries. The emphasis was to be directed solely at getting a cost reducing application of castings to a part which had formerly been produced by another process.

Eligibility was planned to be as open as possible. Excluded were Foundry Department personnel and certain other employees, ineligible because of general company rules. Joint entries were encouraged. As far as possible, the administrative control of entries was left to appropriate managers in the customer departments. This was done to minimize misunderstandings concerning credit for ideas and like problems.

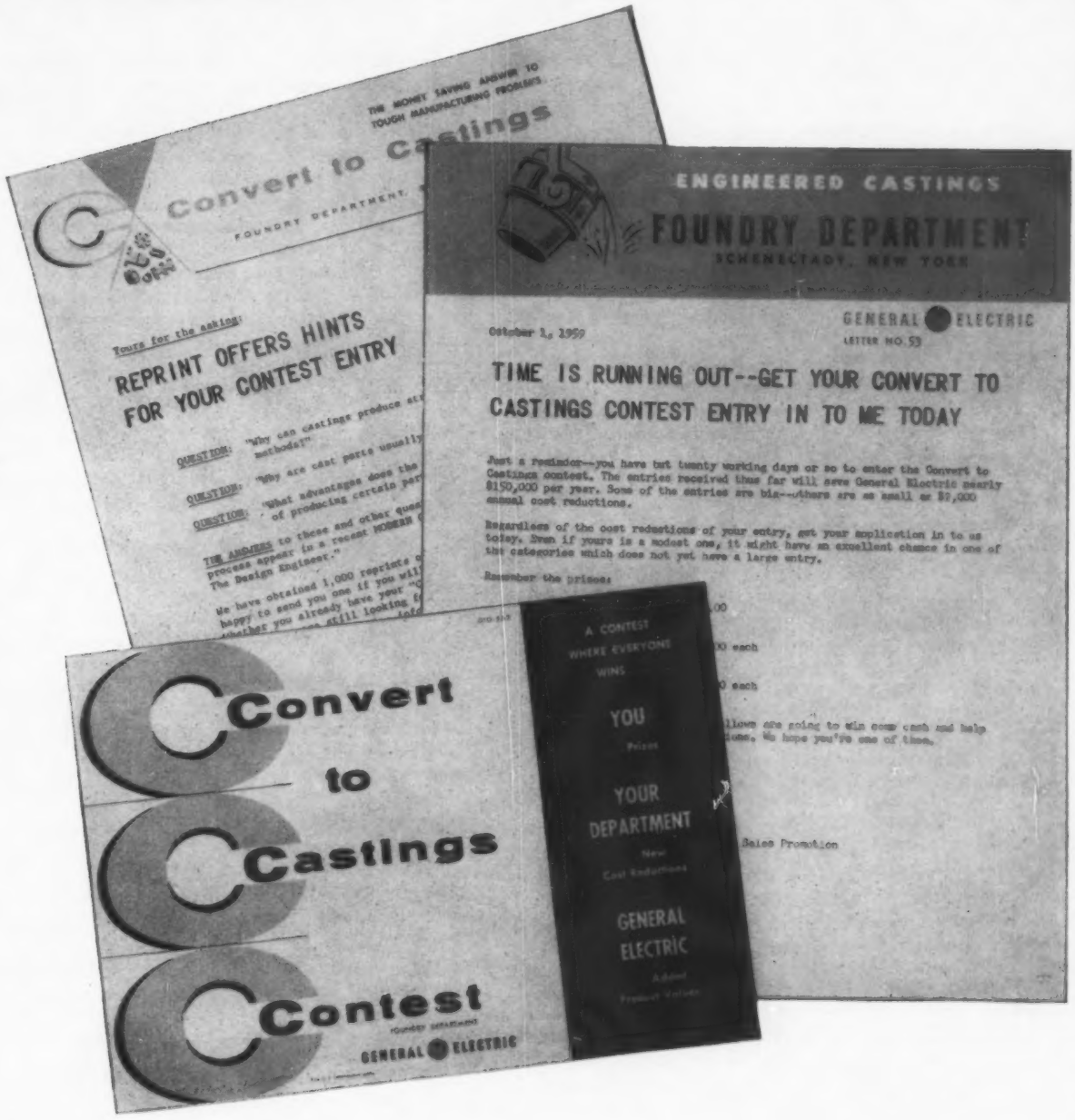
Prizes

The prizes were planned with these factors in mind.

1. Prizes must be large enough to provide real motivation to engineers and other professional people. With joint awards expected, the reward to an individual must be a significant amount.

2. There must be a sufficient number of awards to encourage widespread participation. We were anxious to attract small entries as well as large ones because some of the former ultimately could be expected to grow into large amounts of new business.

Prizes for five separate product lines (gray iron, malleable and special irons, steel, non-ferrous, and


Convert to Castings
FOUNDRY DEPARTMENT
Yours for the asking:
REPRINT OFFERS HINTS FOR YOUR CONTEST ENTRY
ENGINEERED CASTINGS
FOUNDRY DEPARTMENT
SCHENECTADY, NEW YORK
GENERAL ELECTRIC
October 1, 1959
LETTER NO. 53
TIME IS RUNNING OUT--GET YOUR CONVERT TO CASTINGS CONTEST ENTRY IN TO ME TODAY
Just a reminder--you have but twenty working days or so to enter the Convert to Castings contest. The entries received thus far will save General Electric nearly $150,000 per year. Some of the entries are big--others are as small as $2,000 annual cost reductions.
Regardless of the cost reductions of your entry, get your application in to us today. Even if yours is a modest one, it might have an excellent chance in one of the categories which does not yet have a large entry.
Remember the prizes:
Sales Promotion
Convert to Castings Contest
GENERAL ELECTRIC
A CONTEST WHERE EVERYONE WINS
YOU
YOUR DEPARTMENT
GENERAL ELECTRIC

specialty castings) partially solved the small entries problem. Also, ten additional honorable mention prizes were designed to encourage small entries.

3. Total cost of the awards had to be kept in reasonable relationship with the results expected.

The understanding and enthusiastic acceptance of key managers in customer departments was recognized as essential. There was even some risk that if the contest were not clearly understood, it might be resented as an improper attempt to influence customers in making decisions among alternate manufacturing processes.

This problem was discussed in advance with several of our larger customers so that potential pitfalls could be identified. Two weeks in advance of the campaign, top managers in all departments of the Company received an announcement of the coming contest and the proposed rules (preceeding page).

Several enthusiastic responses were received. There were no unfavorable comments in the intervening two weeks, so the campaign was released. A blanket announcement was mailed to 4000 key people in one of the regular monthly sales promotion letters.

At the time of this first announcement, a letter was sent to all Managers-Manufacturing and Managers-Engineering enclosing contest announcements and entry blanks for distribution to individuals who might

not be reached by the mass mailing. The announcements were in a form suitable for use on bulletin boards. Many of them appeared in engineering offices, in drafting rooms, value analysis offices, and other key spots throughout customer plants. These silent reminders to consider castings may have been the most valuable contribution of the whole campaign. We know of no other way to have gained such prominent display for our products in so many key places.

Throughout the campaign, regular monthly letters emphasized, reminded, and prodded readers about the contest.

Through sales representatives, we found that a number of good entries weren't going to be finished in time to meet the August 31 deadline. Therefore, the contest was extended two months, which proved to be the most productive period of the contest. Also during this time, we really "turned on the heat" with urgent reminders (see page 53).

When the judging was completed, publicizing the winners provided further opportunity to advertise castings. Major awards were presented at recognition luncheons, timed for just a few days before Christmas. Photographs and stories appeared in company publications, local newspapers and the trade press. Some local radio stations picked up the story for use in their newscasts.

Participants and their managers have been pleased and proud of the accomplishments. In fact, the general manager of the department which won the grand prize arranged for a special display for several of the executive officers.

Winning Conversions

The grand prize winner was an excellent example of team effort. It was won by a cost reduction team from Small Steam Turbine Department at Fitchburg, Mass. Members of the team were: L. T. Janowski, design engineer; L. E. Santerre, manufacturing engineer; T. A. Flint, cost accountant; and H. G. Laakso, buyer.

The conversion was worked out with the help of W. P. Dotter, manager-sales; A. S. Melilli, casting design engineer; and others from the Everett Foundry.

The winning casting was a turbine wheel casing. Formerly it had been produced in the customer's own shop as a combination of castings and weldments. It was re-designed as two steel castings—upper and lower. Also, the foundry agreed to cast both halves to dimensions close enough that machining of the bore could be eliminated. The re-design also eliminated a vertical joint which had been a troublesome cause of steam leaks.

Total annual savings were $48,597, or a reduction of 48 per cent on those operations affected by the change.

This conversion was the result of an excellent team effort of customer personnel, foundrymen, and a casting design engineer. The foundry provided an improved cast product, the customer got a solid improvement in product quality and a healthy cost improvement as well. Future parts of this type will undoubtedly be designed as castings.

Another interesting conversion entry grew out of an idea at a Value Analysis class in a customer department. The project leader was F. E. Lawson, value analyst in the Ordnance Department. Other participants in the project were Robert Fischer, Andrew A. Pink, and Thomas Sedgewick.

The product was a 16-piece weldment used on a missile launching device. Over 75 lineal feet of welding was required and machining was difficult. It was re-designed as two castings. Savings on one size alone were $25,056 per year. This case also was a team effort with A. J. Lomasney, manager-sales and E. S. Frens, casting design engineer participating.

Savings were calculated:	
Cost of part as manufactured at present	$628.00
Cost of part as made as a casting	367.00*
Savings per casting	261.00
Anticipated annual use	96 pcs.
Estimated annual savings	$25,056

*Includes pattern, test bars and drafting time.

This conversion is providing an improved product for an equipment which is very important in our national defense. It is also helping in a small way in the campaign to get more defense per dollar. The four participants in the Ordnance Department shared an award of $300 for this accomplishment.

One of the most interesting entries was submitted by J. W. Albright, representing an unnamed group of design and manufacturing engineers in the Power Transformer Department. At their request, the $300 award was turned over to the Pittsfield Boy's Club, Pittsfield, Mass.

The part, an adapter, was made as a weldment. It was re-designed as an aluminum casting with annual savings of $27,386.

As indicated in the following calculation there were substantial savings both in material and labor costs.

	Material	Labor
Cost of part as manufactured at present	$87.66	$9.12
Cost of part as made from a casting	27.32	2.48
Saving per casting	$60.34	$6.64
Anticipated annual use		375
Estimated annual savings		$27,386*

*Based on utilizing tools and pattern over three years.

Contest Evaluation

Here is our evaluation of the campaign:

1. Validated annual cost savings of $217,000.
2. Substantial increase in castings business.
3. Increased acceptance by our customers of castings as an engineering material.

Cost

Prizes	$2200
Promotion costs (approx.)	$2800
Total cost (approx.)	$5000

So successful has been the effectiveness of the Convert to Castings contest that in the post-contest publicity, we announced there will be another contest in the spring.

Five New Tests for Controlling Shell Molding Sand Mixtures

Foundrymen now have five new tentative standards by which to exercise quality control over sand mixtures used for shell molding and coremaking. These tests have been developed through the extensive efforts of members of the Shell Mold and Core Committee (8-N), Sand Division, American Foundrymen's Society. Details are given for determining melt point, hot tensile strength, hot deflection, transverse strength, and permeability.

MELT POINT FOR SHELL MOLDING SAND MIXTURES

Melt point of shell molding sand mixtures is the temperature at which the shell mix melts and adheres to a heated metal bar.

Melt Point Apparatus

A gradiently heated metal bar shall be used providing a temperature range of 110 to 250 F. (figure 1). Suitable means shall be provided for determining the temperature along the bar. This can be done with inserted thermometers, thermocouples, or pyrometer.

Test Procedure

When the bar is hot, wipe or spray with a thin film of silicone release agent. Spread mix evenly, approximately 1/16 inches thick, three inches along the bar in the estimated melt point range.

After ten seconds, brush the mix with a soft hair brush from the cold toward the hot end of the bar. A fine air jet held two to three inches from the bar can also be used. At the place where the mix adheres to the bar, record the temperature. The average of three readings shall be recorded as the melt point of the shell mix.

HOT SHELL TENSILE STRENGTH

Hot shell tensile strength is the tensile strength of a shell specimen taken when it has cured and is still hot.

Specimen Forming Apparatus

The specimen is formed in a standard AFS tensile briquette shape having 0.250 ± 0.010-inch

thickness. The single cavity metal pattern is split through the 1.000-inch dimension of the pattern cavity. The pattern should be heated between thermostatically controlled curing blocks (figure 2). Provision must be made to prevent lateral movement of the pattern halves without restricting longitudinal movement.

Procedure for Forming Test Specimen

Place the split pattern on the lower curing block. Fill the hopper strike-off assembly with shell mix so that the mix in the pocket is level with the ends, see figure 3. With the pattern and the top and bottom curing blocks at the desired temperature, coat the pattern with release agent, rest the strike-off edge of the hopper strike-off assembly against the edge of the open cavity in the pattern.

Dump the sand into the cavity in one swift motion. Place the strike-off edge along the longitudinal center line of the pattern and move the blade first in one direction from the center line and then in the other direction from the center line, keeping the blade perpendicular to the pattern. The excess mix shall be completely removed from the pattern.

Immediately place the top curing block on top of the pattern, and time the curing operation. The top block must not touch the specimen. The curing time and temperature may be selected to match operating conditions, or to develop the full properties of the binders.

Hot Shell Tensile Test Apparatus

The hot shell tensile specimens shall be tested while they are in the tensile pattern on a dynamic load instrument equipped to provide heat on both sides of the pattern (figure 2). The instrument shall be designed to load the specimen at a constant rate with a minimum of friction between the pattern and the hot plates.

A suitable indicator shall record the load at the breaking point of the specimen. The loading apparatus shall be capable of applying loads from 150 to 600 pounds per square inch.

Hot Tensile Test Procedure

Immediately after the curing cycle, start the instrument loading mechanism. When the specimen is broken, record the breaking load in pounds and calculate the tensile strength in pounds per square inch for each specimen.

Six specimens constitute a test of one sample for the evaluation of shell mixtures. Three specimens constitute a test for process control. The recorded hot tensile strength value for the sample should be the average of the tensile strength in pounds per square inch of the six or three specimens.

HOT SHELL DEFLECTION

Hot shell deflection is the movement of a transverse shell specimen under load when subjected to uni-directional heating.

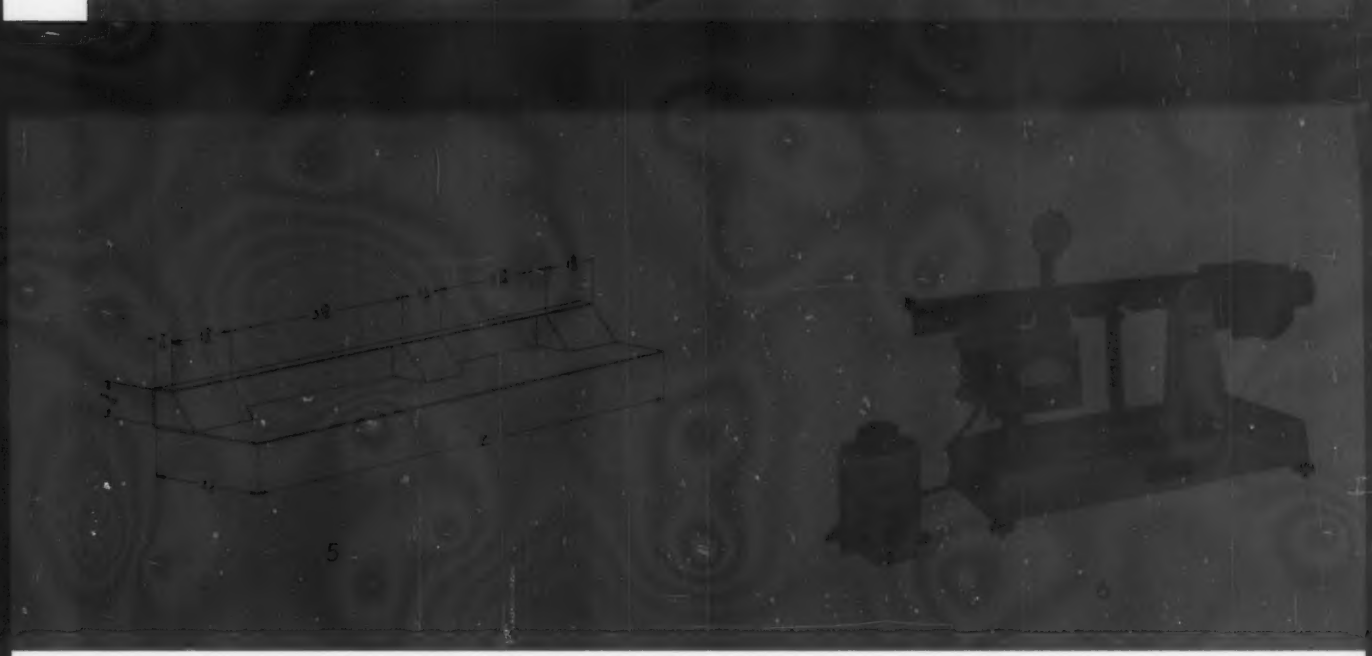
The deflection at a given time can be in opposition to the load, due to the expansion of the heated surface, or it can be in the direction of the application of load due to the deformation of the shell structure under load. The direction of the movement and the amount shall be noted along with the operating temperature and load applied to the specimen.

Specimen Forming Apparatus

The specimen is formed in a split pattern which may be heated in an oven, or between thermostatically controlled curing blocks (figure 4). The split pattern shall produce specimens 1/4 inch x 1 inch x 4 inches.

Procedure for Forming Test Specimens Using Curing Blocks

Place the split pattern on the lower curing block and coat with release agent. Fill the hopper strike-off assembly, (figure 4) with sand so that the sand in both pockets is level with the divider plate. With the top and bottom curing



blocks set for the desired temperature, rest the strike-off edge of the hopper strike-off assembly against the edge of the open cavities in the pattern.

Dump the sand into the cavities in one swift motion. Place the strike-off edge along the longitudinal center line of the pattern and move the blade first in one direction from the center line and then in the other direction from the center line, keeping the blade perpendicular to the pattern. The excess sand shall be completely removed from the pattern.

Place the upper curing block on the specimens and time the curing operation. The curing time and temperature may be selected to match operating conditions, or to develop the full properties of the binders. When the specimens are cured, remove them from the pattern and cool to room temperature before testing. Record weight and thickness of specimens before test.

Procedure for Forming Specimens using an Oven

Coat the pattern assembly with release agent and heat to test temperature in oven. Fill the hopper strike-off assembly with sand, so that the sand in both pockets is level with the divider plate (figure 5). Remove the pattern assembly from the oven and let it cool 25 F. below test temperature, as measured on the base plate. Rest the strike-off edge of the hopper strike-off assembly against the edge of the open cavities in the pattern.

Dump the sand into the cavities in one swift motion. Place the strike-off edge along the longitudinal center line of the pattern and move the blade first in one direction from the center line and then in the other direction from the center line, keeping the blade perpendicular to the pattern. The excess sand shall be completely removed from the pattern.

Place the pattern filled with sand in the oven at a predetermined temperature for a given time. Specimens are to be cooled to room temperature before testing. The weight and thickness of the specimens should be recorded before testing.

Hot Shell Deflection Test Apparatus

The hot shell deflection specimens shall be tested on a static-load instrument equipped to provide heat from one direction and to indicate the deflection of the specimen under the influence of heat and the static load (figure 6).

The instrument shall be designed to support the specimen between 3-inch centers and to load the specimen with, or against, a 1-inch square block that may be heated to temperatures up to 2000 F. The block shall be positioned at the center of the specimen.

The dial indicator shall measure the deflection of the specimen on the side opposite the center of the heating block. The loading apparatus shall be capable of applying loads up to 4 pounds. One type of a commercially available unit is shown in figure 6. This is a loaded beam device and the loading and measuring system of this unit is illustrated in figure 7.

Another useful method is shown in figure 8. This device employs a block with a known weight which is heated to operating temperature and placed directly on the specimen. The deflection of the specimen is measured with a dial indicator mounted below the specimen.

Test Procedure with Loaded Beam Apparatus

Fit the transverse specimen into the specimen holder grips of the test apparatus. The specimen should be positioned with the smooth side down. Raise the screw supporting the load bar so that the specimen does not rest against the reference block.

Move the sliding weight to the desired load, for instance, 1.5 pounds. Back off the screw supporting the loading bar so that the specimen supports the static load

between the reference block and the knife edges.

Adjust the dial indicator so that the indicating hand is free to move at least two revolutions in each direction. Adjust the temperature of the hot block in the furnace until its temperature reaches the desired level. The voltage should be such that there is little loss in temperature when the specimen is being heated. Remove the cover enclosing the hot block and index the furnace so that the hot block is beneath the specimen.

Lower the loading bar holding the hot block, and measure the movement of the sand specimen under the influence of the load and temperature. Note the dial indicator readings at periodic time intervals until the readings become constant, or until the specimen's surface is destroyed under the influence of heat. Test at least five specimens in this manner; plot the average values of deflection against time for the mix.

Two values may be expressed in reporting the test results. One is the maximum movement in opposition to the load and the other is the movement in the direction of the load application at a selected time interval.

Test Procedure with Fixed Weight Method

Center a transverse specimen on the knife edges with the smooth side of the specimen down. Bring the loading block to operating temperature. The block shall have a 1-inch square base and the apparatus shall include means for aligning block in center of specimen.

Place the reference block on the specimen. This block shall be identical in weight and base dimension with the hot block. With the room temperature reference block in position, adjust the dial indicator so that the indicating hand is free to move at least two revolutions, or 0.2 inches in each direction.

When the zero adjustment is completed, remove the reference block and center the hot block on the specimen as gently as possible. Note the dial indicator reading at periodic time intervals until the readings become constant, or until the specimen's surface is destroyed under the influence of heat.

Test at least five specimens in this manner; plot the average values of deflection against time for the mix. Two values may be expressed in reporting the test results. One is the maximum movement in opposition to the load and the other is the movement in the direction of the load application at a selected time interval.

SHELL TRANSVERSE STRENGTH

Shell transverse strength is the load required to break a shell specimen 4 inches long, 1 inch wide and 1/4 inch thick when the load is applied midway between the supports bearing the specimen. The distance between supports shall be recorded as well as the load in pounds. This distance shall be 3 inches.

Specimen Forming Apparatus

The specimen shall be formed in a split pattern which may be heated in an oven, or between thermostatically controlled curing blocks (figure 4). The split pattern shall produce specimens 4 inches long, 1 inch wide and 1/4 inch thick.

Procedure for Forming Test Specimens Using Curing Blocks

Place the split pattern on the lower curing block and coat with release agent. Fill the hopper strike-off assembly, (figure 5), with sand so that the sand in both pockets is level with the divider plate. With the top and bottom curing blocks set for the desired temperature, rest the strike-off edge of the hopper strike-off assembly against the edge of the open cavities in the pattern.

Dump the sand into the cavities in one swift motion. Place the strike-off edge along the longitudinal center line of the pattern and move the blade first in one direction from the center line and then in the other direction from the cen-

ter line, keeping the blade perpendicular to the pattern. The excess sand shall be completely removed from the pattern.

Place the upper curing block on the specimens and time the curing operation. The curing time and temperature may be selected to match operating conditions or to develop the full properties of the binders.

When the specimens are cured, remove them from the pattern and cool to room temperature before testing. The weight and thickness of the specimens should be recorded before testing.

Procedure for Forming Specimens Using an Oven

Coat the pattern assembly with release agent and heat to test temperature in oven. Fill the hopper strike-off assembly with sand so that the sand in both pockets is level with the divider plate (figure 5). Remove the pattern assembly from the oven and let it cool 25 F. below test temperature, as measured on the base plate. Rest the strike-off edge of the hopper strike-off assembly against the edge of the open cavities in the pattern.

Dump the sand into the cavities in one swift motion. Place the strike-off edge along the longitudinal center line of the pattern and move the blade first in one direction from the center line and then in the other direction from the center line, keeping the blade perpendicular to the pattern.

Place the pattern filled with sand in the oven at a predetermined temperature for a given time. The specimens are to be cooled to room temperature before testing. The weight and thickness of the specimens should be recorded before testing.

Shell Transverse Apparatus

The apparatus described in the section on baked transverse testing may be used for shell transverse tests when provided with suitable adapters to handle transverse specimens 4 inches long, 1 inch wide and 1/4 inch thick.

The test apparatus shall provide means for loading the specimens midway between supports positioned 3 inches apart. One type of commercially available apparatus is shown in figure 9.

Test Procedure

Place the specimen on the supports of the testing machine so that the smooth side of the specimen rests on the two bearing knives and the single-loading knife edge rests on the side of the specimen that was struck off.

Apply load midway between the supports. Record the breaking load in pounds. Test at least 10 transverse test specimens. Specimens that are manifestly faulty shall not be considered in determining the transverse strength. The average of the acceptable values shall be reported as the transverse strength of the group. When the deflection of the specimen is to be measured as well as the breaking load, a minor preload shall be applied to assure proper contact before adjusting the deflection indicator, or recorder.

SHELL PERMEABILITY

Shell permeability is the capacity of a cured 1/4-inch thick shell specimen to allow gas to pass through. It is determined by measuring the rate of gas flow through a 1/4-inch thick specimen, 2 inches in diameter, using a nozzle opening diameter of 0.707 inches and standard pressure.

Specimen Forming Apparatus

The specimen shall be formed in a split pattern which may be heated in an oven, or between thermostatically controlled curing blocks (figure 10). The split pattern shall produce a specimen 2 inches in diameter and 1/4-inch thick (figure 10).

Coat the split pattern with release agent and heat it to test temperature in an oven or between thermostatically controlled curing blocks. When the pattern is heated in an oven, the temperature of the base plate should be measured upon removal from the oven and the sand should be placed in the pattern when the temperature of the base plate has fallen 25 F. below the oven temperature.

When the pattern is heated between curing blocks, the top block shall be removed and the sand placed in the pattern immediately. In striking off the excess sand from the pattern, place the strike-off blade along the longitudinal center line of the pattern and move the blade first in one direction from the center line and then in the other direction from the center line, keeping the blade perpendicular to the pattern. The excess sand shall be completely removed from the pattern.

Cure the specimen between curing blocks or in an oven for the desired time and temperature. The curing time and temperature may be selected to match operating conditions or to develop the full properties of the binders. When the specimen is cured, remove from the pattern and cool to room temperature before testing. The weight and thickness of the specimens should be recorded before testing.

Shell Permeability Apparatus

In addition to a permeability machine as described in the section on green sands, the shell permeability test requires the use of an adapter to fit in the mercury well of the permeability machine, a contact nozzle, and connecting tubing (figure 10).

The contact nozzle shall have 0.707-inch inside diameter so that the height-area ratio will be the same for the shell permeability test as that for the other permeability tests using a 2-inch x 2-inch specimen. The contact nozzle shall be provided with a soft rubber gasket to maintain a gas-tight seal between the nozzle and the specimen.

Procedure for Forming Test Specimens

The specimen shall be supported so that the air is free to escape after passing through the 1/4-inch specimen. A permeability machine with the required accessories for measuring shell permeability is shown in figure 10.

Place the cured shell specimen in the specimen holder with the struck-off side of the specimen resting in the holder. Raise the drum of the permeability machine.

Hold the contact nozzle against the smooth side of the specimen and place the adapter in the mercury well of the permeability machine. Read the permeability as though the sample were actually an AFS 2-inch x 2-inch diameter specimen.

Engineered Construction—Answer to Durable Wood Patterns

Four-way planning is a must if foundrymen want built-to-take-it wood patterns and core boxes.

A Good Pattern must be the end result of planning between molder, coremaker, patternmaker, and customer. The patternmaker must know the number of castings required so pattern construction meets the rugged demands of production.

To hold a wood pattern to dimensional stability over a long period of time and keep it as free from repair as possible is not a question of building it with a maximum amount of lumber. Past experience shows that the more lumber used the greater the chance of warpage; increased weight could also make it more susceptible to damage in handling. The correct answer lies in engineered construction.

Here are a few suggestions. Construct heads for the pattern backbone simply (figure 1). Two layers of 2-inch pine of good grade, perhaps 6 inches wide and spaced no more than 18 inches apart should be sufficient. Then tie these together with stringers about 2 inches x 5 inches and screw directly to the heads, not notched into them. The latter so-often-applied method only weakens the structure. On the inside of the heads place two stringers, 8 to 10 inches wide, directly to the bottom in an upright position, to strengthen the cope side of the pattern.

Staves or lagging of no less than 1-1/2-inch stock in pine, or 1-1/4-inch mahogany if desired, should run in the direction of the draw and should be no wider than 6 inches with a 1/32-inch space between each board. Figure 2 shows such a section completed.

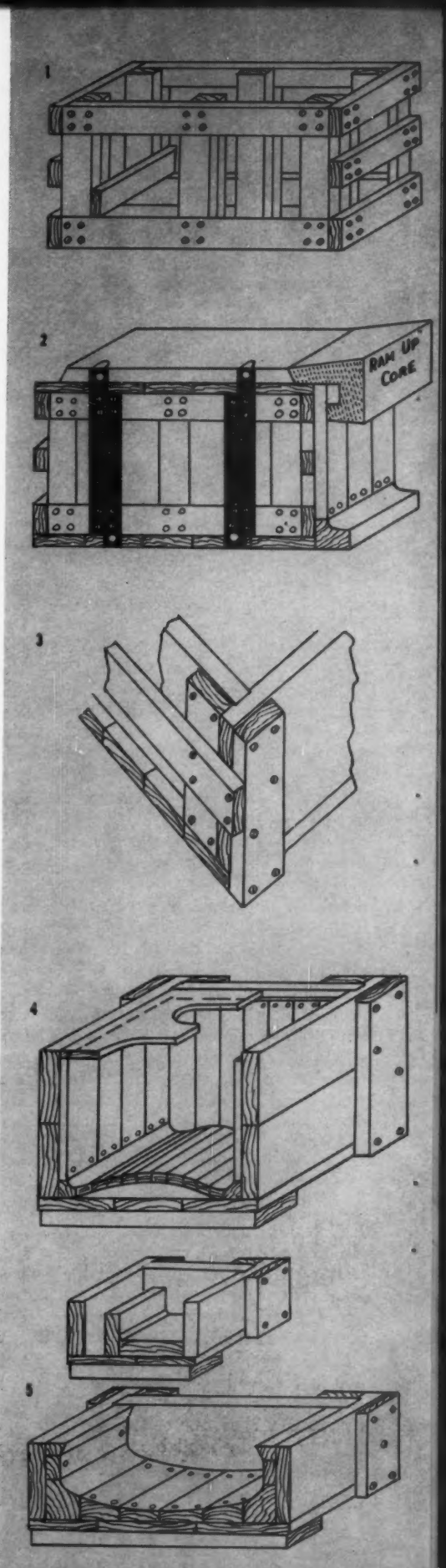
Core-box construction usually begins with a rectangular or square frame of 2-inch lumber. The end should be gained-in 1/4 inch and sturdy 2-inch x 4-inch corner braces should be installed (figure 3). All outside battens are screwed on without any glue. This permits removal for quick replacement. We prefer the rectangular or square design as a safety factor. A large round box, for instance, is hard to handle and could lead to accidents during roll-over.

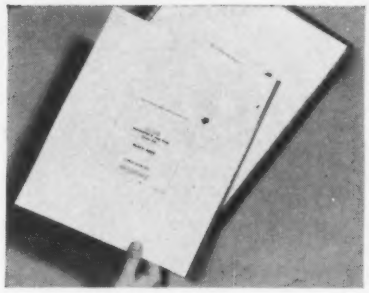
Figure 4 shows what might be applicable to all inside construction of all large boxes—sturdy outside frame, inside lagging with the grain in the direction of draw and forming a seat for loose piece on top.

Figure 5 shows merely detail of the additional core boxes which form the hypothetical bed pattern for a machine tool casting.

The ever-present human weakness of wanting something good, for nothing, usually adds up to a pattern that is good for nothing.

Editor's Note: At the request of Modern Castings, *Walter H. Siebert, production manager of Cleveland Standard Pattern Works, prepared the foregoing practical list of hints.*





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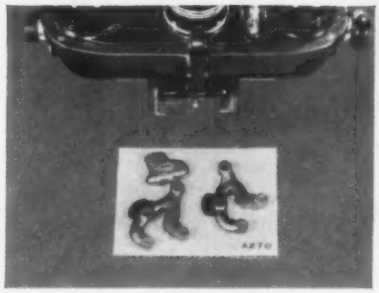

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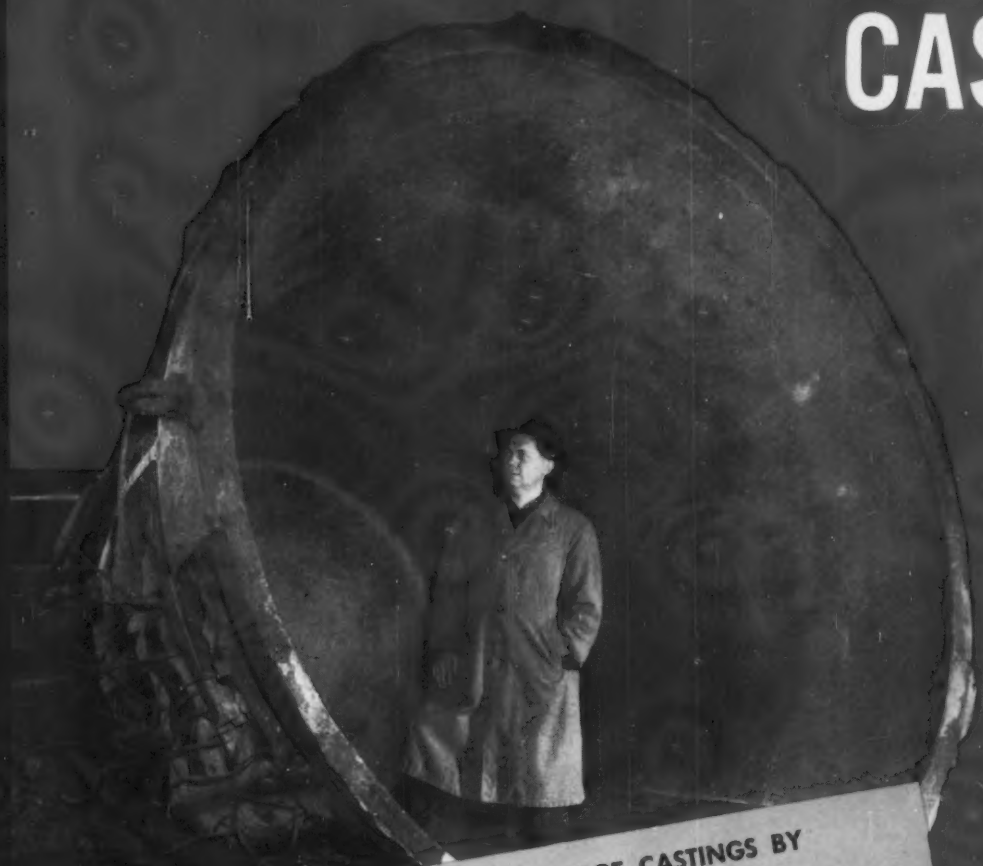

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Knight LETTER (ONE OF A SERIES)

To: Foundry Management

Subject: Foundry Modernization, Mechanization, Automation

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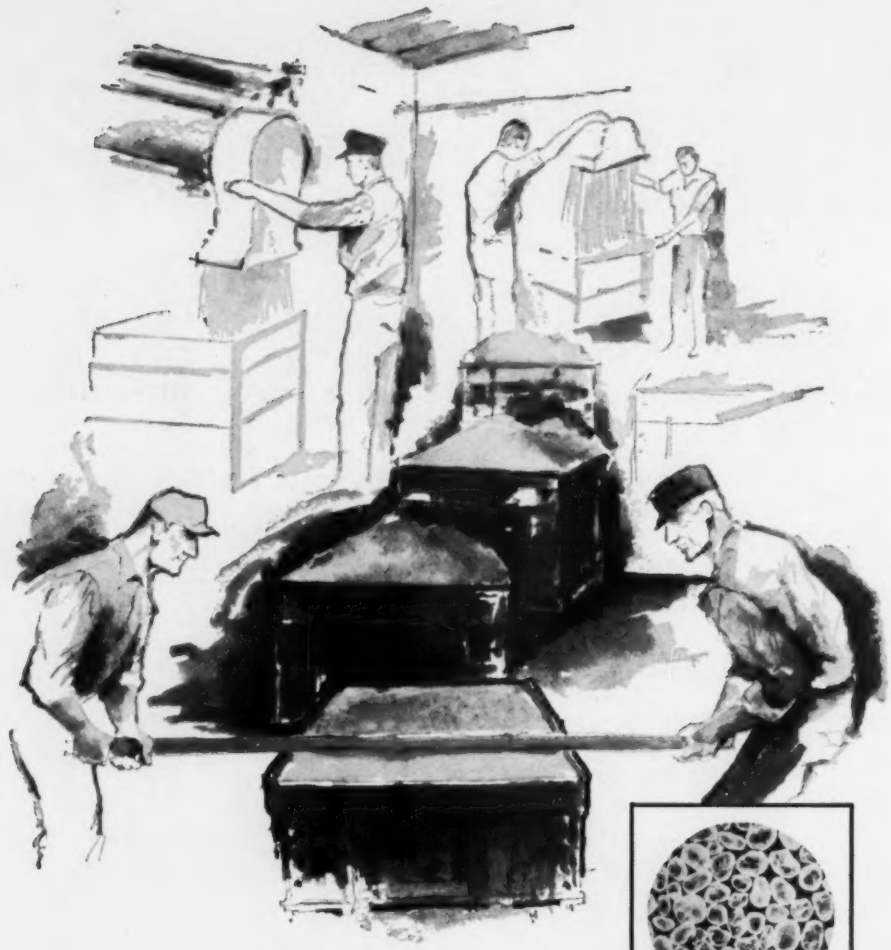

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Circle No. 168, Page 161

CASTING QUALITY CHART

HIGH QUALITY engineered castings are the trademark of success in today's highly competitive markets. Never before in the history of metalcasting have foundrymen been so "quality conscious". Our current technical literature reflects this upsurge of interest. More articles are appearing on such vital subjects as—statistical quality control, non-destructive testing, value analysis, radio-isotopes, electronic moisture control, etc.

In keeping with this high-level interest MODERN CASTINGS presents in the next three pages a "Casting Quality Chart" tailored to the needs of foundrymen using sand for molds and cores. Sand and its binders probably contribute more to success or failure in achieving casting quality than any other segment in the metalcasting process. Drawing from his years of experience in testing and controlling molding sand mixtures, Harry W. Dietert has prepared a practical guide for diagnosing and curing casting ailments attributable to sand. An adaptation of his chart is presented at the left and underneath this page.

Across the top of the page are arranged the 14 most frequent problems encountered in working with molding sands. Down the left hand column of the page is listed the 16 principal properties of sand mixtures. Each of these is a variable which foundrymen must understand and learn to control. To use the chart, locate the particular casting defect in which you are interested. Then read down the column until you come to the explanation of the cause and the remedy to apply for curing it. Often you will find more than one cause and remedy for the defect. This arises from the complexity of molding sand technology and the close interrelation between a number of sand properties. The chart is designed for easy removal from the magazine for posting in your quality control department.

CASTING DEFECT	BLOW	DROP	HOT CASTING CRACKS	PIN HOLES	
FINENESS	EXCESSIVE FINENESS—Reduce clay balls and fines. Increase grain size.		EXCESSIVE FINENESS—Increase grain size, reduce fines.	IMPROVE FINENESS—Reduce clay balls.	P In di
MOISTURE	HIGH MOISTURE—Reduce moisture.	LOW OR HIGH MOISTURE—Control moisture.	HIGH MOISTURE—Reduce moisture.	HIGH MOISTURE—Reduce mechanically retained moisture.	H R
PERMEABILITY	LOW PERMEABILITY—Reduce fines or increase grain size to increase permeability.			HIGH PERMEABILITY—Reduce coarse sand grains.	
GREEN STRENGTH		LOW GREEN STRENGTH—Increase clay or bentonite, or add new molding sand.		LOW GREEN STRENGTH—Increase active clay substance.	
GREEN DEFORMATION		LOW GREEN DEFORMATION—Increase mixing time or active clay substance.			
FACING MATERIAL	FACING TOO STRONG—Reduce Additions.			FACING TOO STRONG—Change additions.	IN M cu .
FLOWABILITY		LOW FLOWABILITY, IF DROPS OCCUR IN POCKETS—Decrease stiffness.			
MOLD HARDNESS	HIGH MOLD HARDNESS—Reduce hardness.	LOW MOLD HARDNESS—Improve ramming.	HIGH MOLD HARDNESS—Reduce ramming.		N H un
DRY STRENGTH			HIGH DRY STRENGTH—Reduce plasticity.		HI Re
HOT SPALLING					EX SP no Sc Su Pe
HOT STRENGTH			HIGH HOT STRENGTH—Increase grain size, reduce fines & binders, increase combustibles.		
HOT COLLAPSIBILITY			SLOW HOT COLLAPSIBILITY—Reduce density.		
MOLD ATMOSPHERE				OXIDIZING MOLD ATMOSPHERE—Reduce water vapor, provide reducing atmosphere.	
HOT GAS PRESSURE	HIGH HOT GAS PRESSURE—Reduce moisture, combustible materials & fines.			HIGH HOT GAS PRESSURE—Reduce flow of corrosive gases into mold cavity, check metal.	
HOT DEFORMATION					LO DE Inc
MOLDING	IMPROPER VENTING OF MOLD— Increase or improve venting.	POOR MOLDING—Sand too hot; use proper flask bars, gaggers; strengthen flasks; adjust molding machine; avoid rough handling.	WRONG IN-GATE THICKNESS—Select better in-gate thickness.	IMPROPER MOLDING—Increase venting and pressure head.	

Adapted by Modern Castings from a chart developed by Harry W. Dietert, Harry W. Dietert Co., Detroit, Mich. ©1957, H.W.D. Co.

Casting defects are shown in capital letters, and the remedies follow immediately after.

CASTING QUALITY CHART

RAT TAILS	DIRT	SCAB	CUT	ROUGH SURFACE	ME METAL
POOR FINENESS—Increase grain distribution by one sieve.		EXCESSIVE FINENESS—Increase grain size, reduce fines.		COARSE FINENESS—Improve grai reduce fineness, or add fines.	
HIGH MOISTURE—Reduce moisture.	LOW MOISTURE—Control moisture at correct temper.	HIGH MOISTURE—Reduce moisture.	HIGH OR LOW MOISTURE—Control moisture.	HIGH OR LOW MOISTURE—Control moisture.	
		LOW PERMEABILITY—Increase grain size or reduce fines.		HIGH PERMEABILITY—Reduce coarse sand grains.	HIGH Reduce grains,
	LOW GREEN STRENGTH—Increase mixing energy or increase bond.	LOW GREEN STRENGTH—Increase strength.	LOW GREEN STRENGTH—Increase mixing or clay substance.	HIGH GREEN STRENGTH—Reduce clay substance.	
	LOW GREEN DEFORMATION—Increase mixing time or active clay substance.	HIGH GREEN DEFORMATION—Reduce moisture.	LOW GREEN DEFORMATION—Increase mixing time or active clay substance.		
INFERIOR FACING MATERIAL—Increase cushioning materials.	IMPROPER FACING MATERIAL—Improve quality and distribution of facing material in mold.		FACING TOO WEAK—Increase additions.	INFERIOR FACING MATERIAL—Check quality—for example—volatiles, sulfur, combustion rate.	INFERI MATER wash,
		HIGH FLOWABILITY—Increase grain size.		LOW FLOWABILITY—Increase by decreasing stiffness; reduce clay substance and sand grain size.	LOW F Increa stiffnes excessi or grai
NON-UNIFORM MOLD HARDNESS—Control for uniform hardness.	NON-UNIFORM MOLD HARDNESS—Control mold hardness.	HIGH MOLD HARDNESS—Reduce ramming or tooling.	LOW MOLD HARDNESS—Increase ramming.	LOW MOLD HARDNESS—Improve ramming energy.	LOW M Increa
HIGH DRY STRENGTH—Reduce dry strength.	LOW DRY STRENGTH—Increase plasticity of green mixture.		LOW DRY STRENGTH—Increase plasticity of green mixture.		
EXCESSIVE HOT SPALLING—Refer to notes at right under Scab, Cut, Rough Surface, Mechanical Penetration.	EXCESSIVE HOT SPALLING—Stabilize sand.	EXCESSIVE HOT SPALLING—Make sand thermally stable by changing clay substance or sand grains, or by additions of cereals or cellulose. Improve density and expansion relation between sand and protective coating; reduce thickness of the coating.			EXCESS SPALLI wash
			LOW HOT STRENGTH—Increase by selecting new sand, binde such as silica flour or mixture of western bentonite and Ohio		
	RAPID HOT COLLAPSIBILITY—Retard this tendency.				RAPID COLLA Retard clay mixture size; core m
		HIGH HOT GAS PRESSURE—Increase grain size, reduce moisture and combustibles.			
LOW HOT DEFORMATION—Increase hot deformation.	LOW HOT DEFORMATION—Increase cellulose or cereal.	LOW HOT DEFORMATION—Add cellulose material.			
	POOR MOLDING—Improve handling, finishing and gating.	IMPROPER MOLDING—Reduce tooling, improve gagger practice and metal entrance into mold.	IMPROPER MOLDING—Reduce sand temperature, improve gating.	IMPROVE MOLDING—Use facing mold and core coatings.	

MECHANICAL METAL PENETRATION	OXIDE METAL PENETRATION	VEINING	DIFFICULT SHAKE OUT	STICKINESS
rove grain distribution, ines.			EXCESSIVE FINENESS—Increase grain size; reduce fines.	
	HIGH MOISTURE—Control moisture.		HIGH MOISTURE—Reduce moisture.	HIGH MOISTURE—Reduce high mechanically held moisture.
HIGH PERMEABILITY—Reduce coarse sand grains, add fine sand.		HIGH PERMEABILITY—Increase fines or distribution.	LOW PERMEABILITY—Increase grain size; reduce fines.	HIGH PERMEABILITY—Reduce coarse grains.
		LOW GREEN STRENGTH—Increase clay substance.	HIGH GREEN STRENGTH—Reduce clay substance or select new binders.	LOW GREEN STRENGTH—Increase mixing efficiency and clay substance.
				LOW GREEN DEFORMATION—Increase active clay substance.
INFERIOR FACING MATERIAL—Improve wash, control glazing.		IMPROPER FACING MATERIAL—In core mixtures add iron oxide, clay substance, fines; reduce organics.	IMPROPER FACING MATERIAL—Select special compounded materials.	POOR FACING MATERIAL—Improve uniformity and selection.
LOW FLOWABILITY—Increase by decreasing stiffness; reduce excessive cereal and clay or grain size.				
LOW MOLD HARDNESS—Increase ramming energy.			HIGH MOLD HARDNESS—Reduce ramming energy.	
			HIGH DRY STRENGTH—Reduce moisture.	
EXCESSIVE HOT SPALLING—Stabilize wash and mold surface.	HIGH HOT SPALLING—Decrease spalling and cracking.			
d, binders, or additives d Ohio clay.			HIGH HOT STRENGTH—Change clay or add cellulose.	
RAPID HOT COLLAPSIBILITY—Retard by increasing clay substance in core mixture; reduce grain size; increase binder in core mixture.		RAPID HOT COLLAPSIBILITY—Retard by adding iron oxide clay substance, fines, silica flour.	SLOW HOT COLLAPSIBILITY—Reduce fines, clay substances, fluxes; increase carbon carrying or producing materials.	
	OXIDIZING MOLD ATMOSPHERE—Provide reducing or inert mold atmosphere, reduce water vapor, oxygen, carbon dioxide.			
	LOW HOT GAS PRESSURE—Increase reducing atmosphere.			
		LOW HOT DEFORMATION—Increase hot deformation		
facing sand, protective				POOR MOLDING—Reduce temperature difference between sand & pattern; use pattern spray.

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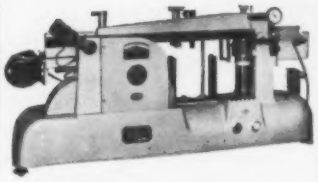

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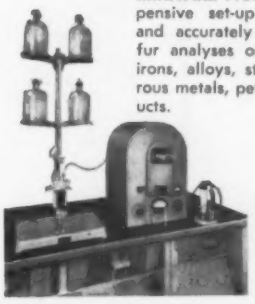

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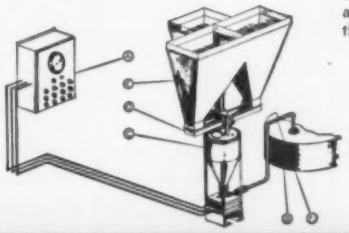

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Castings Congress Papers

S. C. Massari

Once again MODERN CASTINGS *is privileged to present five exclusive Castings Congress Papers containing tomorrow's technology. Subjects range from a theoretical appraisal of sand angularity factors to a practical roundup of aluminum die casting practices in Britain. These are balanced off with articles covering the Shaw process, vacuum induction melting of steel, and ladle additions to gray iron.*

TECHNICAL HIGHLIGHTS

Sand Angularity and Shape Factors .....p 73

Attempts have been made to relate the ratio of sand permeability and sieve analysis to produce an angularity factor. This factor has been used to describe sand shapes, interpreting sharp corners, edges or surfaces or designating numerically shapes as they depart from the spherical. The authors claim this method cannot be used to describe shape of sands because it cannot distinguish between even simple geometric shapes. The microscope still remains the only tool capable of assigning a relative shape.

Shaw Process Patterns .....p 83

The Shaw process is a precision casting method that eliminates use of expendable patterns and has no known size limitations. Extremely accurate molds and castings are obtained from a permanent pattern. Process is particularly suited for casting-to-size permanent molds, core boxes and shell molding patterns. A finely powdered refractory is mixed into a slurry with a colloidal suspension of silica in alcohol. Slurry is poured over pattern and quickly solidifies. Pattern is removed when mold is passing through a rubber-like phase. Mold is ignited and surface becomes microcrazed. This condition imparts an unusual resistance to thermal shock of molten metal.

Vacuum Induction Melting of Steel .....p 95

High strength steels can be made even tougher and more ductile by vacuum induction melting. Compared with melting in air, the yield strength (0.1%) increased from 218,000 psi to 233,000 psi; elongation, from 5.9 per cent to 8.6 per cent; and reduction of area, from 9.1 per cent to 20.3 per cent. These improvements are attributed to lowering of residual gas content and great reduction of nonmetallic inclusions. Final contents of oxygen, hydrogen, and nitrogen are 0.0003, 0.00001, and 0.0005 per cent respectively. Formation of silica inclusions is prevented because vacuum keeps oxygen content below the solubility product curve for silicon and oxygen.

Ladle Additions to Gray Iron .....p 113

Because many ladle inoculants contain combinations of silicon, calcium, carbon and aluminum, the authors examined the separate effects of these elements on hypoeutectic iron. Late additions of pure silicon did not favorably alter microstructure, nor elevate eutectic temperature, nor nucleate solidification of eutectic temperature, nor nucleate solidfication of eutectic liquid, nor reduce chilling tendency. Metallic calcium additions had exactly the opposite effects on iron. Graphite had same effects as calcium. Aluminum additions did not improve transverse strength properties nor produce Type A graphite; but it did reduce chill, elevate eutectic solidification temperature, and increase solidification nuclei.

Aluminum Alloy Die Casting .....p 123

Both pressure and gravity die casting practices in Britain are described. Contrary to the U. S. trend, gravity die casting (the equivalent of permanent mold casting in U. S.) accounts for more aluminum production than pressure die casting. This all-inclusive roundup covers: casting tolerances and surface finish, casting machines, die design, alloys cast, mechanization, and quality control. Future trends will include more extensive use of vacuum die casting, bigger and higher pressure machines, more mechanization, and auto-ladling.

The AFS Castings Congress papers are the most authoritative technical information available to the metalcasting industry. Over 100 papers were prepared by close to 250 authors and presented at the 1960 Congress in Philadelphia, May 9-13. Papers receive preview publication in MODERN CASTINGS and then are bound into the annual volume of AFS TRANSACTIONS for permanent reference. All papers have been approved by the appropriate Program and Papers Committee of the sponsoring AFS Technical Division. They are then edited by AFS staff members C. R. McNeill and M. C. Hansen. Written discussion of these papers will be welcome.

SAND ANGULARITY AND SHAPE FACTORS

Surface area measurements and theoretical and experimental relationship

by G. J. Vingas and A. H. Zrimsek

ABSTRACT

Theoretical concepts of describing shapes, sharp corners, edges and surfaces of foundry sands by numbers and ratios of surface area to volume are comprehensive but limited. The microscope still remains the only tool capable of assigning a relative shape.

INTRODUCTION

Shape factors for small particles were introduced by Fair and Hatch (1933),[1] using the background material of Green (1927),[2] Martin (1923)[3] and the Corps of Engineers (1930),[4] where surface area to volume ratios were factored by the use of statistical mean diameters, volumes and surface areas.

Dallavalle and Goldman (1939)[5] used this method based on Carman's[6] equation measuring surface area from air permeability tests. Davies[7] used the above data and information and applied it to foundry sands. Hofmann[8] renewed Davies'[7] interest, simplified the permeability test and introduced factors to compute theoretical spherical surface areas from the sieve analysis.

Theoretically, Davies attempted to use permeability as a means of determining actual surface area, and the sieve analysis to determine the theoretical surface area with the assumption that all the sand grains are spherical. The ratio of these two measurements he called angularity factor.

The purpose of this paper is to show the limitation of the surface area to volume measures in describing shapes, interpreting sharp corners, edges or surfaces or designating numerically shapes as they depart from the spherical.

The conception of

$$E = \frac{SW}{Sth} \text{ (Formula 1-1).}$$

E = angularity.
SW = actual surface area.
Sth = theoretical surface area.

G. J. VINGAS is Rsch. Engr. and A. H. ZRIMSEK is Fdy. Engr., Magnet Cove Barium Corp., Arlington Heights, Ill.

is also theoretically and experimentally invalid in comprehensibly describing angularity.

The air permeability method is also discussed, with its limitations and abilities in measuring surface area as such and how it compares with other methods.

THEORY

There is a common misconception that when equal diameters are considered, the SA/V factor for the sphere is considered the lowest. This statement is wrong. Only when equal volumes are considered is the SA/V ratio the lowest for the sphere.

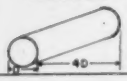
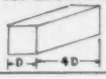
When screening sands through a Tyler screen, the main controlling factor is *D* (D = diameter or the side of the square opening of the sieve). Any simple euclidean shape, whether spherical, cylindrical or pyramidal, will pass through the screen if two of the smaller dimensions are equal or smaller than *D*.

Table 1 shows eight euclidean regular geometrical shapes that will pass a screen opening of diameter *D* with formulas calculating their surface area and volumes in relation to *D* (D = screen size opening).

Table I also computes the surface area/gram of sand, the number of particles/gram of sand for the simple euclidean shapes passing the 40 mesh and retained on the 50 mesh. (D = 0.356 mm, which is the size opening of an average of 40 and 50 mesh square screens used in the standard AFS method.)[9]

Assuming that the permeability method will accurately measure the actual surface area of the aggregate (later in this paper a discussion is presented on this subject), a shape factor is computed for the cube by using Formula 1-1. The theoretical surface area of 1 gram of sand 63.7 cm^2 is divided by 63.7 cm^2, which is the theoretical surface area of one gram of spherical sand retained on the same screen; an angularity factor of one is obtained. If any angularity factor of 1.0 means that the material is spherical and that the number increases as the angularity increases, it is needless to say that numbers below 1.0 would not be possible as there is no shape which could be more spherical than the sphere.

TABLE 1 — AREAS, VOLUMES AND THEIR RELATIONSHIP

	SPHERE	CYLINDER 	CUBE	PARALLELOPIPED 	SQUARE PYRAMID
1 AREA	πD^2	$4\frac{1}{2}\pi D^2$	$6 D^2$	$18 D^2$	$3.24 D^2$
2 VOLUME	$\frac{1}{6}\pi D^3$	πD^3	D^3	$4 D^3$	$\frac{1}{3} D^3$
3 AREA / VOLUME — RATIO	6 / D	4.5 / D	6 / D	4.5 / D	9.72 / D
4 POSSIBILITIES OF PACKING %SOLIDS MAX.	74.05	60.46	100.00	100.00	100.00
5 MIN.	52.40	15.00	50.00	15.00	50.00
6 SURFACE AREA	$S = A\pi D^2$	$= A 4\frac{1}{2}\pi D^2$	$= A 6 D^2$	$= A 18 D^2$	$= A 3.24 D^2$
7 MASS OR WEIGHT	$P = A\frac{1}{6}\pi D^3\delta$	$= A\pi D^3\delta$	$= A D^3\delta$	$= A 4 D^3\delta$	$= A\frac{1}{3} D^3\delta$
8 NUMBER OF PARTICLES PER GRAM	$A = 6P/\pi D^3\delta$ $A = 15,850$	$= P/\pi D^3\delta$ $= 2,642$	$= P/D^3\delta$ $= 8,296$	$= P/4D^3\delta$ $= 2,074$	$= 3P/D^3\delta$ $= 24,888$
9 SURFACE AREA IN SQUARE CENT. PER GRAM	$S = 6P/D\delta$ $S = 63.7$	$= 4.5P/D\delta$ $= 47.8$	$= 6P/D\delta$ $= 63.7$	$= 4.5P/D\delta$ $= 47.8$	$= 9.72P/D\delta$ $= 107.0$
10 ANGULARITY FACTOR S_W / S_{TH}	$63.7/63.7$ $= 1.00$	$47.8/63.7$ $= .75$	$63.7/63.7$ $= 1.00$	$47.8/63.7$ $= .75$	$107.0/63.7$ $= 1.68$
11 SPECIFIC SURFACE AREA IN SQUARE CENT. PER PIECE	.004	.018	.0077	.023	.0043
12 SPECIFIC VOLUME IN CUBIC CENT. PER PIECE	.000024	.00014	.000045	.00018	.000015
13 DIAMETER OF SPHERE TO ACCOMODATE SURFACE AREA IN CENT.	.0354	.065	.044	.07	.03
14 SURFACE AREA / VOLUME RATIO PER PIECE	166	129	171	128	287
15 SURFACE AREA / VOLUME RATIO IF SPHERE	166	94	135	85	189
16 PERCENT SPHERICITY SPECIFIC SHAPE NUMBER	100	73	79	66	66

FOR 8 SIMPLE EUCLIDIAN SHAPES

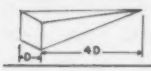
SQUARE PYRAMID 	TRIANGLE PYRAMID	TRIANGLE PYRAMID
$9.12\ D^2$	$2.13\ D^2$	$6.59 D^2$
$1.33\ D^3$	$\frac{1}{6}\ D^3$	$\frac{2}{3}\ D^3$
$6.84 / D$	$12.78 / D$	$9.88 / D$
100.00	100.00	100.00
15.00	15.00	50.00
$= A 9.12\ D^2$	$= A\ 2.13\ D^2$	$= A\ 6.59\ D^2$
$= A \frac{1}{3} D^3 \delta$	$= A \frac{1}{6} D^3 \delta$	$= A \frac{2}{3} D^3 \delta$
$= \frac{3P}{4 D^3 \delta}$ $= 6{,}222$	$= \frac{6P}{D^3 \delta}$ $= 49{,}776$	$= \frac{3P}{2 D^3 \delta}$ $= 12{,}444$
$= \frac{6.84P}{D\delta}$ $= 72.6$	$= \frac{12.66P}{D\delta}$ $= 135.0$	$= \frac{9.88P}{D\delta}$ $= 105.0$
$\frac{72.6}{63.7}$ $= 1.14$	$\frac{135.0}{63.7}$ $= 2.12$	$\frac{105.0}{63.7}$ $= 1.65$
.0117	.0027	.0085
.00006	.0000076	.00003
.048	.024	.039
195	356	283
120	237	160
61	66	57

TABLE 1 LEGENDS

S — Surface area.
D — Diameter of screen 0.354.
A — Number of particles.
P — Mass or weight of sand.
δ — Specific gravity.

Table 1 line 10 lists the angularity factors for a variety of shapes. These factors show the cube with a factor of 1.0 and the parallelopiped and the cylinder with a factor of 0.75. In the case of the pyramids, when the height equals *D*, the angularity factor is 1.68 for the square pyramid and 2.12 for the triangle. As the height increases to 4D, the square pyramid's factor drops to 1.14 and that of the triangle pyramid to 1.65. The above proves the inability of this method to assign a shape factor.

Obviously, then, the theoretical concept is fallacious, as it cannot distinguish nor assign theoretically numbers to express shapes, angularity nor deviation from sphericity.

SPECIFIC SURFACE AREA, VOLUME AND SHAPE

The method of computing or assigning angularity numbers to sand, interpreting sharp corners, edges or surfaces, as stated by Davies and later Hofmann, is not accurate. As shown above, they cannot distinguish cubes from spheres or cylinders. A further effort was made to evaluate specific surface area, specific volume and specific shapes as a means of numerically describing shapes as they depart from the spherical.

Specific Surface Area

The specific surface area factor is the number of square centimeters/piece of sand. To determine this number, measuring the surface area/gram by the air permeability method, and the rather tedious procedure of counting pieces/gram, is necessary. A simple calculation of the number of pieces/gram and the surface area measured assigns the specific surface area factor. Here too the main controlling factor is *D* (D = diameter or the edge parameter of the square opening of the sieve). Any simple shape with two of its smaller dimensions smaller than *D* will pass through the screen.

Table 1 line 11 lists the specific surface area in square centimeters/piece in a number of euclidean shapes. Although this method distinguishes spheres from cubes, it cannot assign any comprehensive number to other shapes.

Specific Volume

Specific volume (volume/piece) requires the same tedious procedure as the specific surface area, i.e., measuring surface area by the air permeability method and counting pieces/volume of sand.

Table 1 line 12 lists the specific volumes in cubic centimeters/piece for a variety of shapes. This method shows the same shortcomings as the specific surface

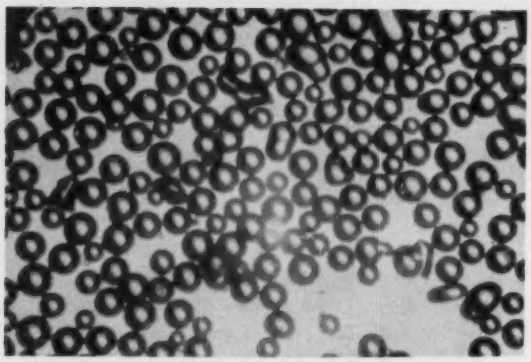


Fig. 1 — Glass beads. Transmitted illumination. 45 ×.

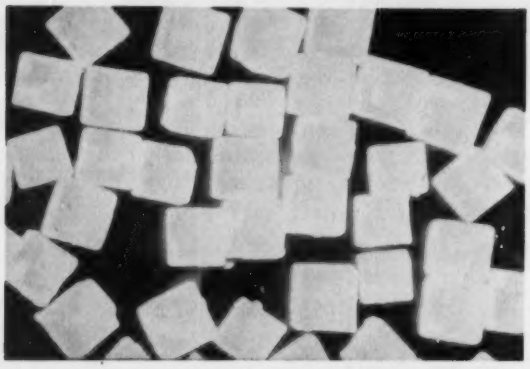


Fig. 2 — Sodium chloride crystals, 50 mesh. Reflected illumination. 45 ×.

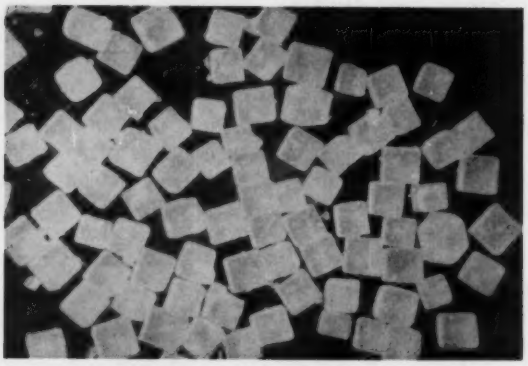


Fig. 2a — Sodium chloride crystals, 100 mesh. Reflected illumination. 45 ×.

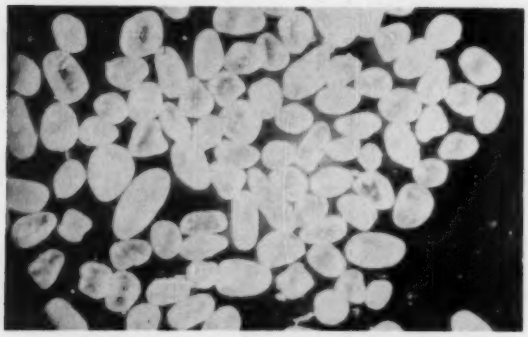


Fig. 3 — Zircon sand, 100 mesh. Reflected illumination. 45 ×.

area method, and cannot assign any comprehensive number describing shapes.

Specific Shape or Sphericity

The specific shape number consists of calculating the ratio of SA/V per piece of sand grain, finding the ratio of SA/V of a sphere of the same volume and reducing the ratio of the two volumes to a percentage. Of course, D (D = diameter or edge parameter of the square opening of the sieve) is the controlling factor. Table 1 line 16 shows the specific shape factor expressed in percentage of sphericity.

Supposedly, the lower the number the more the material departs from sphericity. Although the number distinguishes spheres from cubes, cylinders and parallelopipeds, it confuses the shapes of the pyramids and cones.

GENERAL DISCUSSION

Provided the air permeability method is able to accurately and reproducibly measure surface area, an arbitrary number could be given to any sand comparing SA/V per average piece or per volume of sand, but it could not describe shapes nor distinguish sharp corners, edges or surfaces of sand grains. However, the surface area/grain of sand could be given as such.

EXPERIMENTAL

The theory above clearly indicates that the angularity factor cannot distinguish deviations from sphericity. An experiment was designed to evaluate the angularity factor and the specific shape factor based on the indications and conclusions of the above theory, and to simultaneously evaluate the air permeability method for measuring surface area.

The shapes shown in Table 1 were approximated by using the following materials of one screen size for simplification of calculation.

1) Glass beads (Fig. 1)—spheres.
2) Salt, NaCl, screened and sized (Figs. 2 and 2a) —cubes.
3) Zircon sand, screened and sized (Figs. 3, 7 and 7a)—cylinders.
4) AFS standard sand, Texas river sand, Olivine sand screened and sized (Figs. 4, 5, 5a, 6 and 6a)— Irregular shapes with varying degrees of visual angularity.

The samples were screened, washed with water, dried and rescreened. An air permeability test was conducted at different bed heights and different voids per cent, as shown in Figs. 8, 9 and 10, and the shape factor was calculated, as shown in Table 2. The glass beads were assigned a factor of 1.0, and the other materials were compared with it.

The experimental data agree closely to the theoretical reasoning presented previously. By the use of the angularity factor, the cube showed a factor of 0.98 and the zircon sand considerably less, 0.94 for the 100 mesh and 0.72 for the 200 mesh.

Figures 3, 7 and 7a show that the amount of cylindrical shapes increase from approximately 25 per cent for the 100 mesh to about 75 per cent for the

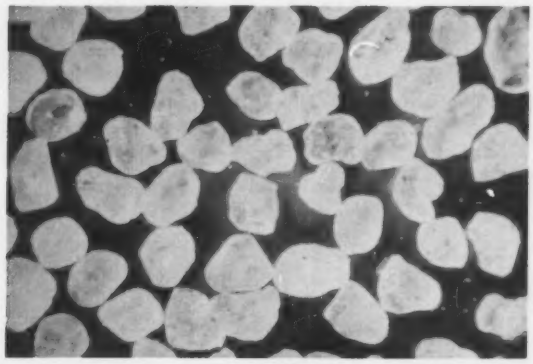


Fig. 4 — AFS standard sand, 50/70. Reflected illumination. 45 ×.

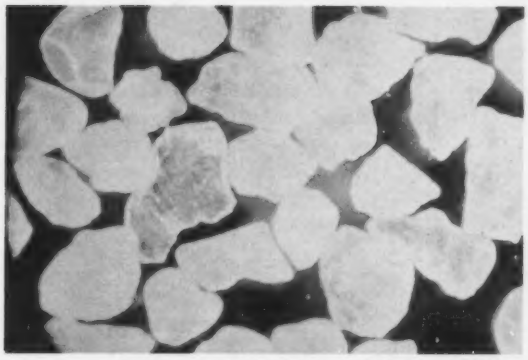


Fig. 5 — Texas river sand, 50 mesh. Reflected illumination. 45 ×.

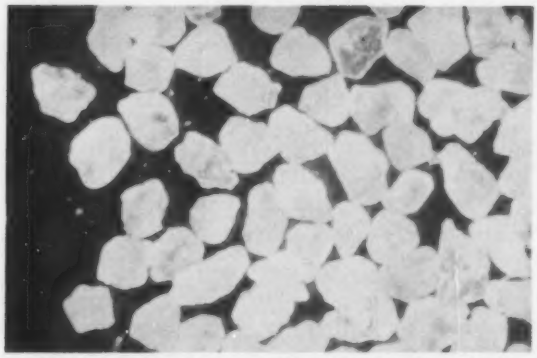


Fig. 5a — Texas river sand, 70 mesh. Reflected illumination. 45 ×.

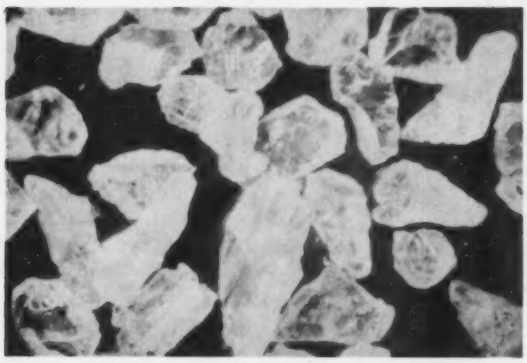


Fig. 6 — Olivine sand, 50 mesh. Reflected illumination. 45 ×.

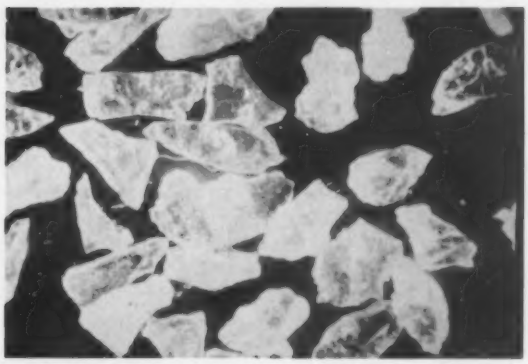


Fig. 6a — Olivine sand, 70 mesh. Reflected illumination. 45 ×.

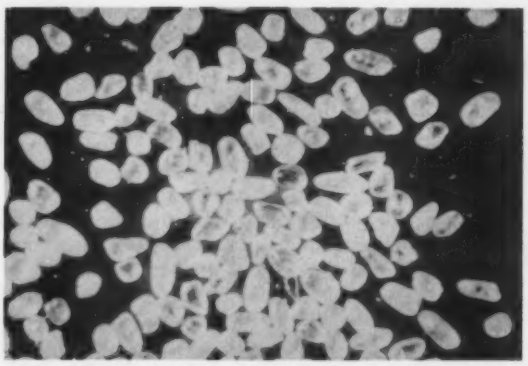


Fig. 7 — Zircon sand, 140 mesh. Reflected illumination. 45 ×.

Fig. 7a — Zircon sand, 200 mesh. Reflected illumination. 45 ×.

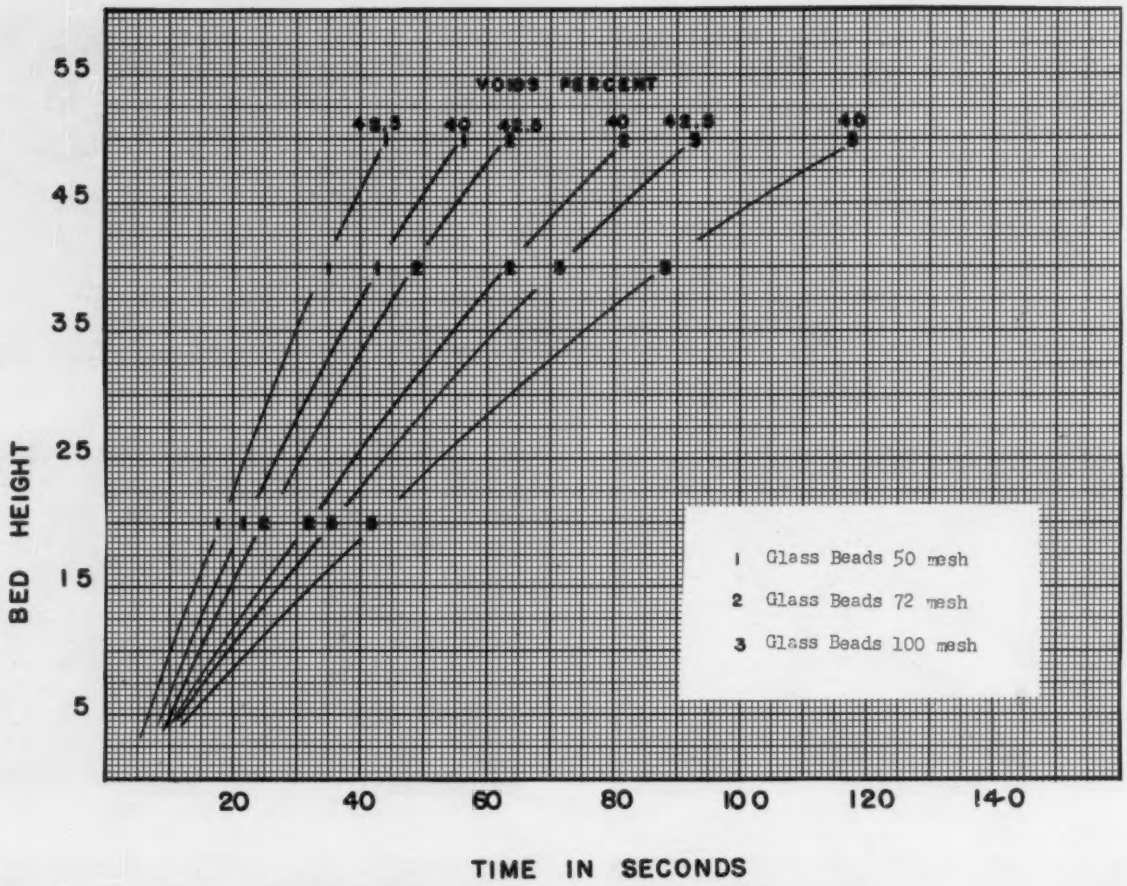


Fig. 8 — Influence of bed height and voids per cent on permeability (time in sec) of glass beads, 50, 72 and 100 mesh size.

200 mesh, which again agrees with the theoretical figures that the cylinders show a factor of 0.75 (Table 1, line 10). Furthermore, this phenomenon was also noticed by Davies (Fig. 11). As the sand size fractions get finer by sieving the angularity factor changes.

Referring to Figs. 1 through 8, it is obvious by visual determination that the standard sand is considerably more angular than the glass beads, but less angular than the observed microscopic angularity of olivine sand. This observed microscopic angularity is not reflected in the angularity factors. Also, reference is made to Rowell's[10] statement that subangular, visually described sands show a lower angularity number than an angular sand.

TABLE 2 — ANGULARITY FACTORS

MATERIAL	SIEVE	FACTOR
Glass Beads	50	1.0
	72	1.0
	100	1.0
	200	1.0
	270	1.0
Salt	50	0.98
	70	0.98
	100	0.98
Zircon	100	0.94
	140	0.83
	200	0.72
Texas Sand	40	1.18
	50	1.18
	70	1.18
Olivine	50	1.39
	70	1.53
Standard 50/70	70	1.09

Specific Shape Factor

From the standpoint of experimentally testing the results of the theoretical reasoning on specific shape factors presented, the glass beads, the standard sand and the salt crystals were counted, and a specific shape (per cent sphericity) was calculated.

The glass beads were assigned a number of 100, and the salt showed 79 per cent sphericity and the standard sand 75 per cent sphericity, which agrees with the theoretical figure (Table 2, line 13) of 79 per cent for the cubes.

There is no question in the minds of the writers that the salt is definitely more angular than the standard sand, as shown in Figs. 2 and 2a.

Surface Area Measurements

The ability of the air permeability method as a measure of surface area has been considered, as well as its relation to other methods such as the micro-

scopic, nitrogen absorption[11] and solubility in hydrofluoric acid.

Figures 8, 9 and 10, plotting time in seconds vs. bed height, show a reasonably good correlation for all material, although the line is lightly curved in the coarse materials as the bed height increases.

Figure 12, plotting the log of $\sqrt{\text{time}}$ vs. standard screen, shows parallel lines for the glass beads and salt where the shape remains constant as the fineness decreases. For the zircon, the slope of the line changes with fineness. This is a reflection of the observation made earlier that the percentage of cylindrical shapes increases with increasing fineness for zircon. Some obvious experimental errors are evident on the graph, especially at the higher porosities, attributed by the writers as a reflection of ununiform packing.

Figures 13 and 14, plotting log of $\sqrt{\text{time}}$ vs. porosity, show the effects of porosity on permeability measures.

In order to use permeability as a determination of surface area, an air permeability test should be made at varying porosities and varying bed heights. After plotting, as shown in Figs. 8, 9, 10, 12, 13 and 14, corrections can then be made against the standard glass beads or salt (NaCl) crystals that will define the slope of the curves.

Many other methods are used, and are described by Cadle[12] and compared in Table 3. In still another method developed by Cross and Zimmerley,[13] where hydrofluoric acid 3.66 normal is used to dissolve the sand in time, and from there extrapolating to the zero time ordinate, the initial rate (IR) or the index of surface is obtained. Table 4 lists an Ottawa silica sand by mesh size. Note that as the sand gets finer the ratio is increasing, which is contrary to the air permeability method, as shown in Fig. 11.

CONCLUSIONS

Angularity factors based on SW and Sth cannot be used to describe shape of sands. This method cannot theoretically nor experimentally distinguish between

TABLE 3

Molybdenum powder surface area as measured per gram by different methods

Median Diameter Microns	Microscope	Nitrogen Adsorption	Air Permeability
14	470	4010	1810
15	440	3120	1510
17	400	3110	1160
30	220	3330	1040

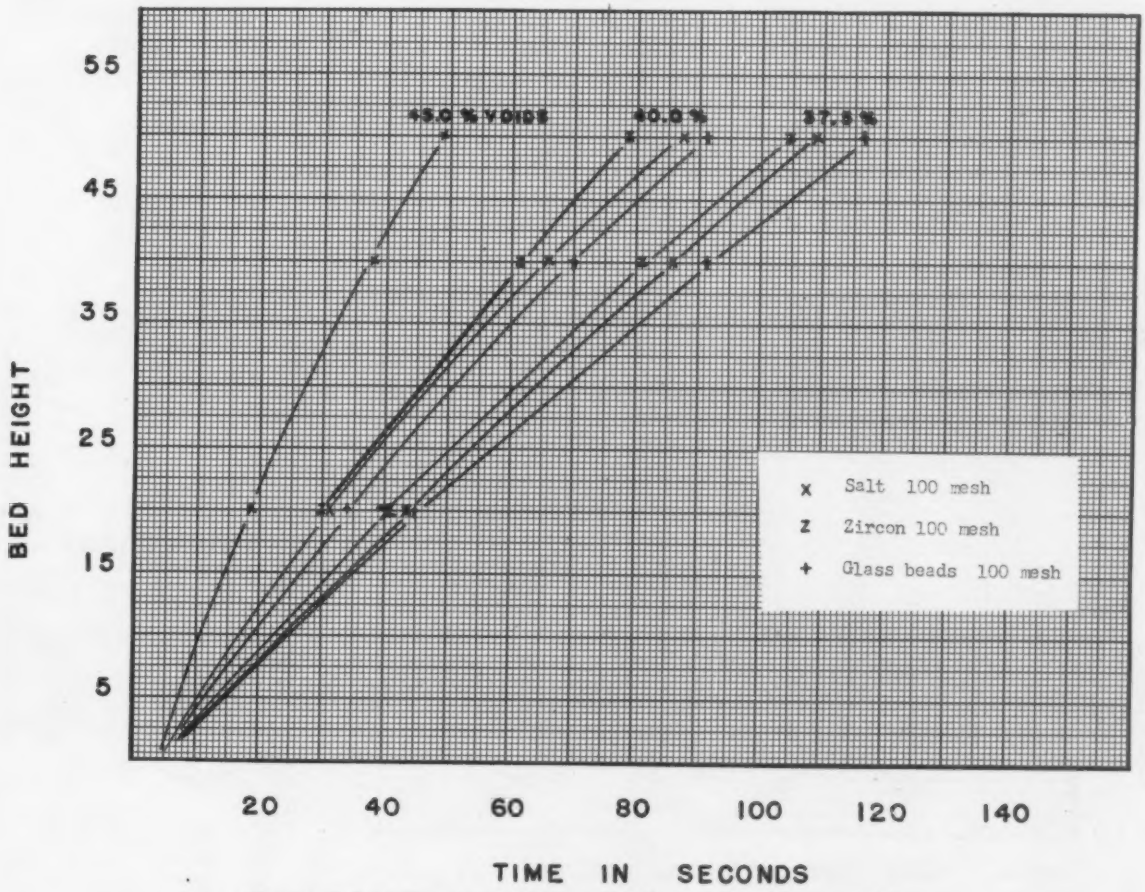


Fig. 9 — Influence of bed heights and voids per cent on permeability (time in sec) of 100 mesh salt, 100 mesh zircon and 100 mesh glass beads.

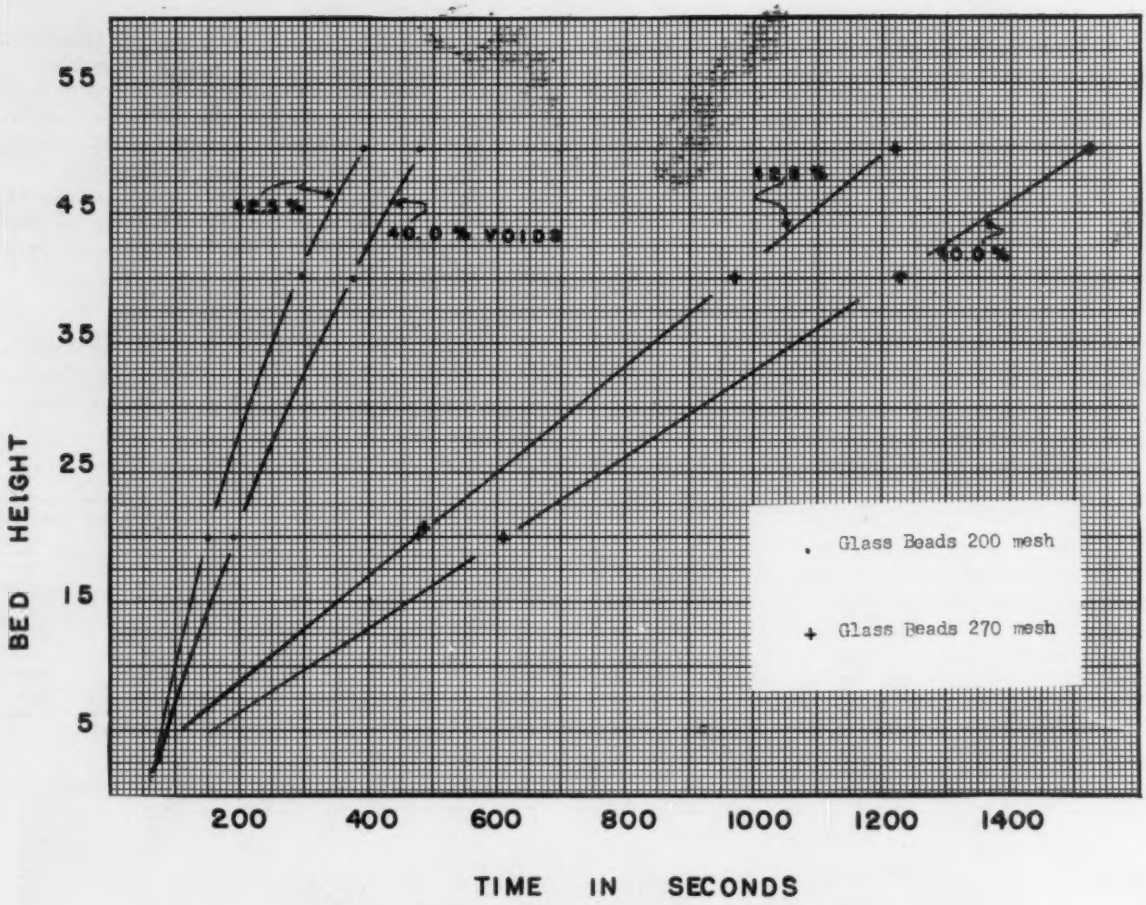


Fig. 10 — Influence of bed height and voids per cent on permeability (time in sec) of 200 and 270 mesh glass beads.

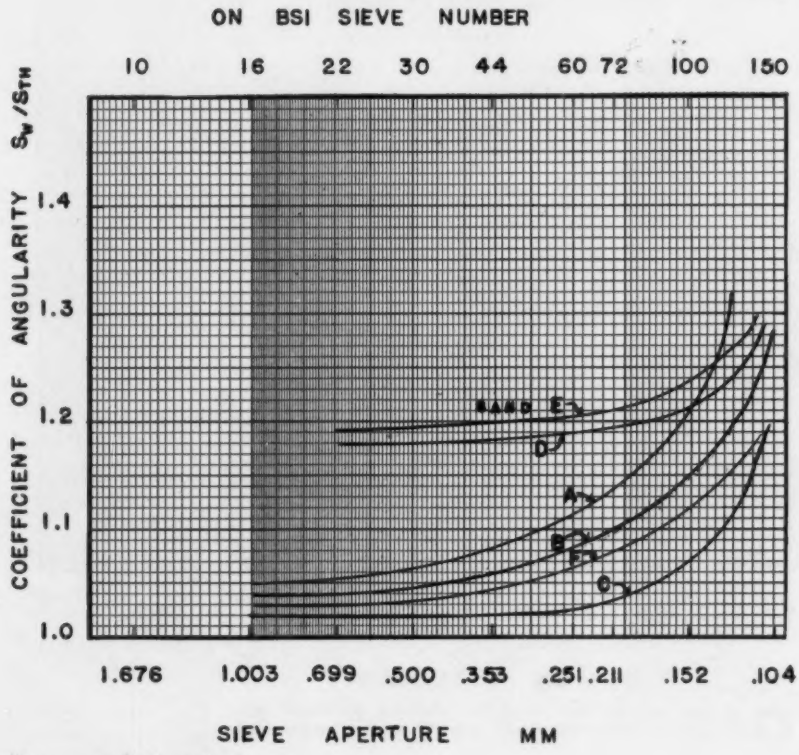


Fig. 11 — Angularity as affected by the change in screen size.

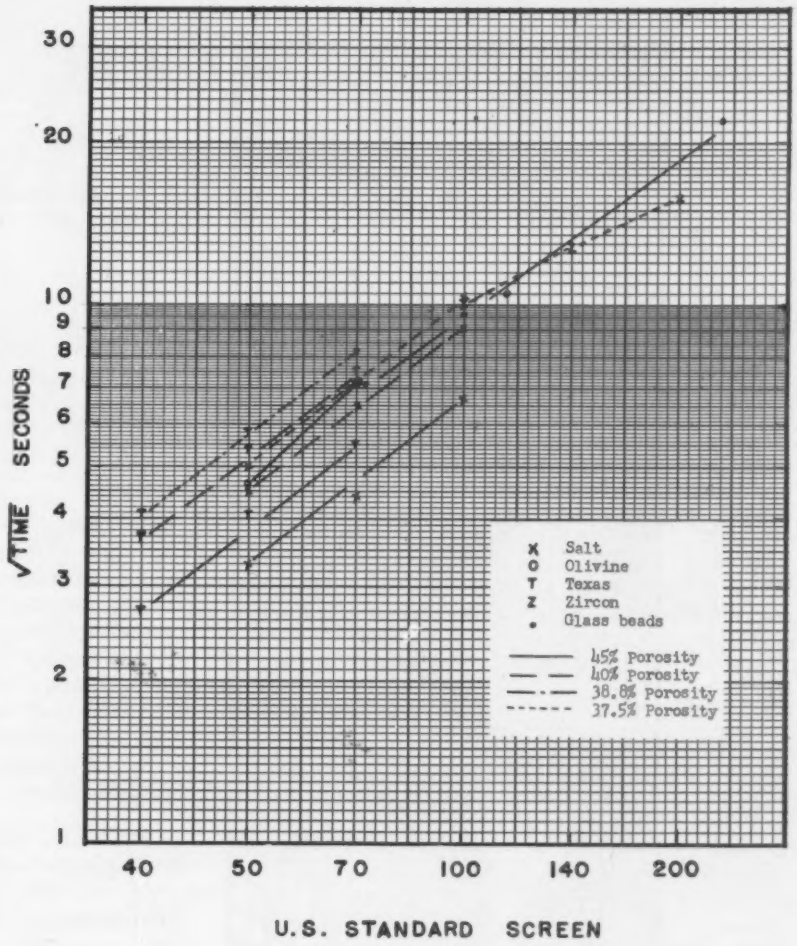


Fig. 12 — Log of time vs. unconsolidated sand retained on standard U.S. screens.

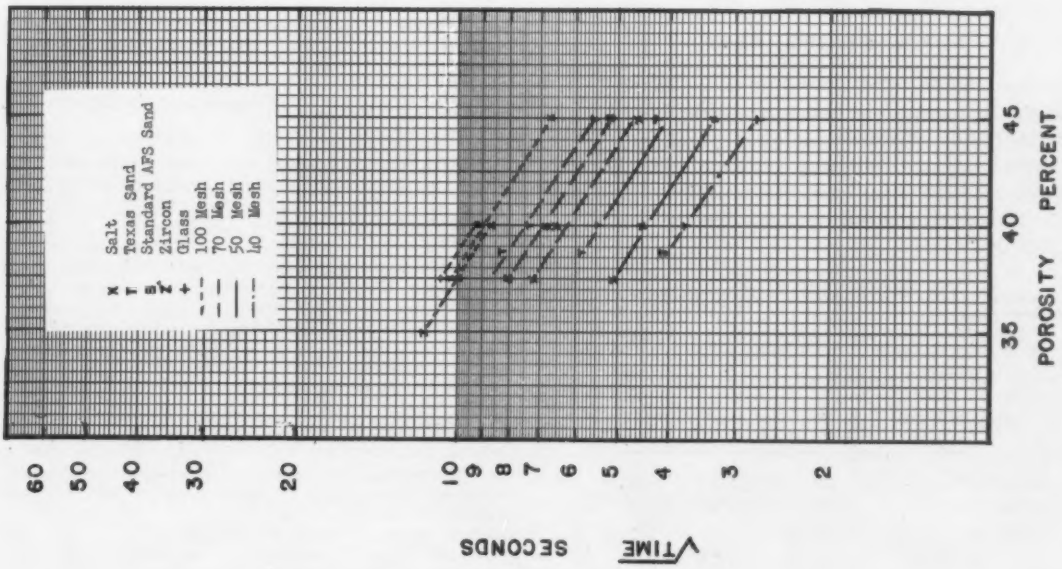


Fig. 13 — Effect of porosity per cent on permeability (time) of various shapes.

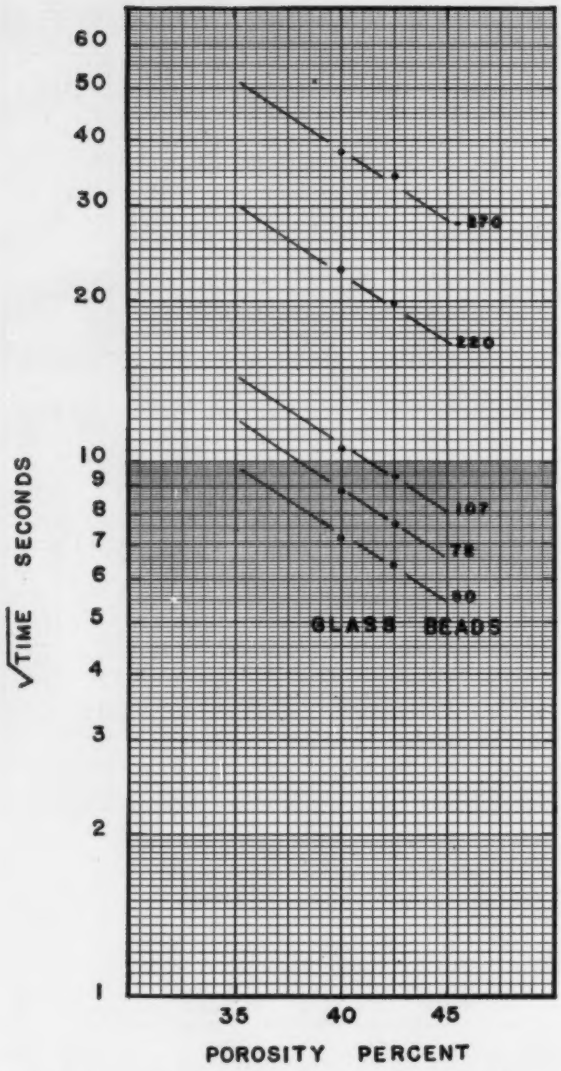


Fig. 14 — Effect of porosity on permeability (time) of various sizes of glass beads.

simple geometric shapes and, therefore, should not be expected to distinguish the more complex shapes encountered in foundry sands.

Specific factors or specific shape numbers cannot give a comprehensive figure describing shape of sands. They are of value when computing energy exerted for new surfaces produced in grinding or crushing operations.

Air permeability method gives a relative value which is controlled by bed height and porosity per cent. Care should be taken to accurately check porosity per cent and bed heights as they greatly overshadow surface area measurements.

The microscope still remains the only means to check angularity.

Recommendations are made to AFS Committee 8-V to pictorially check angularity by ten photographs the same way that grain size is depicted for steel or graphite shape for gray iron.

It is the authors' opinion that surface area is most easily measured by the air permeability method.

TABLE 4 — OTTAWA SILICA SAND SIEVE SIZE DATA

Mesh	Avg. size of Particle, mm	Theoretical surface/g. of quartz spheres, sq cm	Initial Rate, I.R.	Measured surface/g., sq cm,[A] I.R. × 170	Rate of measured to theoretical surface
20/28	0.711	31.8	0.255	43.4	1.37
28/35	0.503	45.0	0.358	60.9	1.35
35/48	0.356	63.5	0.497	84.5	1.33
48/65	0.252	90.0	0.732	124.4	1.38
65/100	0.178	127.0	1.020	173.4	1.37
100/150	0.126	180.0	1.386	235.6	1.31
150/200	0.089	254.0	1.923	326.9	1.29

[A] Calibration Factor.

ACKNOWLEDGMENT

The writers wish to thank the Magnet Cove Barium Corp. for their permission to publish these results. The writers are also indebted to AFS Committee 8-V (Basic Concepts, Sand Div.) for their healthy, stimulating and critical discussion that contributed heavily in making this paper possible.

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SHAW PROCESS PATTERNS PRINCIPLES AND PRODUCTION

by I. Lubalin and R. J. Christensen

ABSTRACT

The subject is covered in two parts. The first part covers the Shaw Process history, molding procedure and some of the various fields of application in this country. The second part is an evaluation of the process and the application of Shaw Process castings to the patternmaking industry.

HISTORY

Many of the newer molding processes in use in this country are the result of our industry applying work done originally in Europe. This is true of lost wax, the Croning process (shell molding), chamotte molding, cement molding and the CO_2 process. The Shaw process was originated in England in 1938. At that time two British scientists, Clifford and Noel Shaw, were working on exploiting the condensation products of ethyl silicate beyond its original use as a preservative for decaying stone work.

In conjunction with two companies, the Shaw brothers commenced the use of ethyl silicate as a binder material for refractory molds. This high temperature binder eventually became the basis for all the modern day lost wax technology both here and in Europe. Acting as technical advisors to the Ministry of Supply on the production of tubine blades, the brothers were involved in the early days of modern precision casting in England.

Being aware of the limitation of the precision methods, the Shaw brothers worked for more than a decade on the development of their new process which would overcome these limitations. In 1951 they commenced licensing the Shaw process in England and on the Continent, and in 1955 Shaw Process Development Corp., a Division of British Industries Corp., was established in Port Washington, N.Y., and licensing commenced in the United States. Today over one hundred licenses involving major foundries, precision casters and tool shops throughout the world, are successfully using this technique.

PROCESS PRINCIPLES

The Shaw process is a method of mold making and precision investment casting without the use of expendable patterns, and with no presently known size restriction. It is unique among casting techniques because of the principle of fine micro crazing developed in the mold. Characteristic also are the resistance of the refractory mold to thermal shock, making possible castings of high accuracy, smooth surface finish and exceptional dimensional stability.

This resistance to thermal shock enables large masses of molten metal to be poured into cold molds without any spalling, washing or cracking due to thermal effect. Extreme accuracy of both mold and casting are obtained from a smooth accurate pattern. Furthermore, since permanent patterns are used, the process is not subject to the shrinkage and distortion problems which occur in lost wax and other investment casting processes patterns prior to investment.

Mold Structure

The basis for the process is the unique structure of the ceramic mold, which depends upon a carefully controlled gelling process initiated by the addition of a gelling reagent to a liquid binder. This binder is comprised of a colloidal suspension of silica in alcohol which has been produced by a controlled hydrolysis.

Finely powdered refractory materials are then added to the liquid binder to form a creamy mobile slurry which is poured over the pattern. As gelling progresses, the slurry solidifies and passes into a tough rubber-like phase. Subsequent stripping in the hard rubber phase and ignition produces the phenomena of micro-crazing, which is the heart of the mold production.

Microcrazing

The mold consists of a silica gel in which is suspended various sized small elements of refractory materials. If a normal cube of silica gel and alcohol is exposed to air, alcohol is lost rapidly. When matter is lost, such as by evaporation from a cube, it adjusts its size in three ways:

1) It shrinks – as in a sintering operation.
2) It cracks grossly such as water and clay.
3) It cracks by fracture in a gel.

In the case of the mold in this process, the issue is forced by greatly accelerating the rate of evaporation by igniting the gel over the entire face of the mold. This results in an exceedingly fine craze cracking looking somewhat like wire netting (Fig. 1). Opening of these minute cracks permits the alcohol underneath the surface to come out, and this procedure continues from the outside in until the

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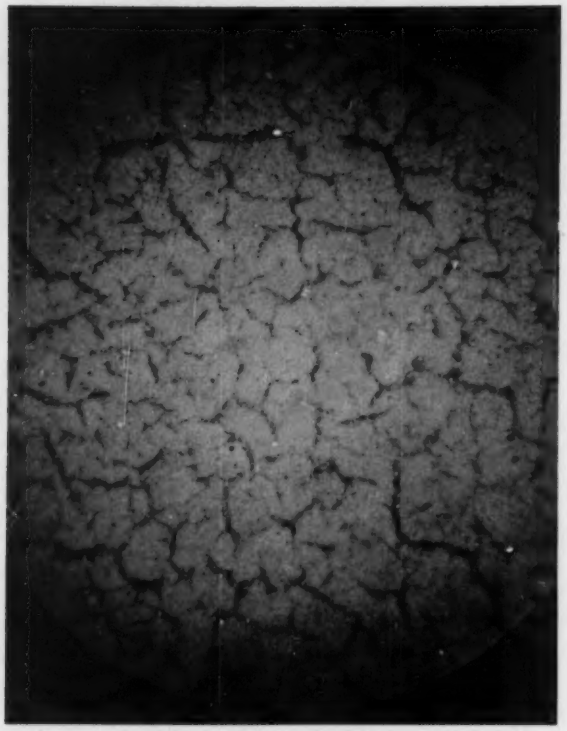


Fig. 1 — Craze cracking which permits alcohol underneath the surface to come out, which continues from the outside in until the entire block of silica gel is craze-cracked.

entire block is completely craze-cracked. Therefore, there are no internal stresses, and matter has been lost without shrinkage or gross cracks but with an enormous number of little cracks.

This results in an infinitely ragged mass of refractory particles bonded with pure silica, so ragged and close together that the particles are mechanically interlocked giving the mass a strength of its own. The appearance is similar to a three-dimensional jigsaw puzzle comprised of a multitude of interlocking segments. In this way a mold structure is produced, which gives these minute fragments the ability to expand and contract without disturbing the adjoining particle.

This results in the following mold characteristics:

Stripability. By stripping during the last phases of the rubbery gel the mold has a slight flexibility, and will deform and spring back to the pattern shape permitting intricate detail and straight walls to be withdrawn without defect.

Resistance to Thermal Shock. Since the individual particles of the mold are free to expand into the craze-cracked fissures when subjected to the high temperature shock of molten steel, no thermal cracking of the ceramic mold occurs. Unlike the other methods of making small precision castings, these molds can readily be poured cold for this reason. Thus, a series of molds can be gathered over a period of time awaiting the accumulation of a full heat.

Dimensional Stability. The molds remain the same size as the pattern throughout their manufacture. Because of the ability of the particles to expand due to the microcrazing, when cast into the molds do not dilate. They are therefore the same size hot or cold, and the coefficient of expansion of the mold is virtually nil. Therefore, the only variant to consider in obtaining accurate dimensions is the contraction of the metal which is dependent on the alloy, its temperature and the configuration of the piece. Once these variables are tied down, reproducibility in tolerance is exceptional. In a batch of 40 castings, one 4½-in. dimension was reproduced within ± 0.004 in.

Collapsibility and Resistance to Tears. Because the molds are already cracked, they give readily during solidification shrinkage and are therefore easy to shake out. Cores also have slight resiliancy enabling them to resist tearing even under arduous conditions. Moreover one of the major causes of hot tearing is mold dilation or growth in the early stages of solidification which does not occur in these molds. Many complex jobs have been cast using this process because of the ability to resist cracking and tearing.

Permeability and Inertness. These two factors are tied together. Because of the ability of the highly refractory molds to withstand chemical reaction and burn in, there is no mold gas formed at the interface. Therefore, the progressive craze cracking is sufficient to act in almost all cases as vents for the gases in the metal.

No Wash or Spalling. This eliminates inclusions. The ability of the ceramic mold to withstand the eroding action of the metal stream, as well as its immunity to thermal shock, means that these molds will not wash or spall, thus eliminating the nonmetallic inclusions which generally arise from this source in sand, shell and investment castings. As compared to the ceramic molds used in lost wax, the absence of thin flaky dip coats eliminates the spalling problem generally associated with this type of mold.

Insulation. Insulation provides superior feeding characteristics, sounder and stronger castings and better detail. This micro-crazing leaves air gaps between the refractory components resulting in an insulating effect. At the same time the use of cold molds promotes a fine grain structure on the surface, while the internal heavy areas can be fed for a considerably longer time than usual. By using refractory materials of much more insulating characteristics in the risering system, directional solidification and excellent progressive feeding can be accomplished. This extreme soundness, along with the elimination of gas and inclusions, results in cast structures having extremely high physicals.

Mold Strength. Mold strength of these ceramic molds is such that all except the large castings can

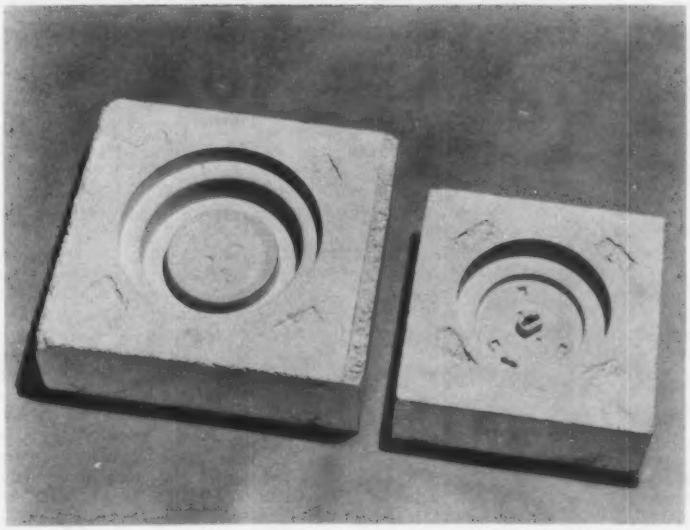
be cast without the necessity of using flasks, and most cores can be produced (solid or hollow) without rodding.

PART 1 — PROCESS SEQUENCE

Slurry Mixing. The mold material is prepared in the form of a slurry by mixing a suitable graded refractory filler with a colloidal suspension of silica in alcohol to which a reagent has been added to produce a carefully controlled gelling reaction. The liquid portion of the slurry is produced by controlled hydrolysis of ethyl silicate. The reaction converting this slurry to a tough rubbery type gel can be represented by the equation Ethyl Silicate plus Water equals Silicic Acid Gel plus Alcohol. Figure 2 shows a refractory material, in this case sillimanite, is mixed together with a binder comprised mainly of ethyl silicate and a gelling agent which controls the gel time.

Slurry Pouring. The slurry is poured over a suitable pattern contained in a leak-proof molding box. The pattern must have a smooth surface to enable the mold to be stripped after gellation has occurred. Subject to this provision any pattern suitable for sand or plaster molding may be used, provided also that the surface is impervious to alcohol. The process is capable of using much more complex patterns than sand or plaster molding, with little or no draft. Figure 3 shows the slurry being poured over a master pattern set in a plaster block odd side and is permitted to gel.

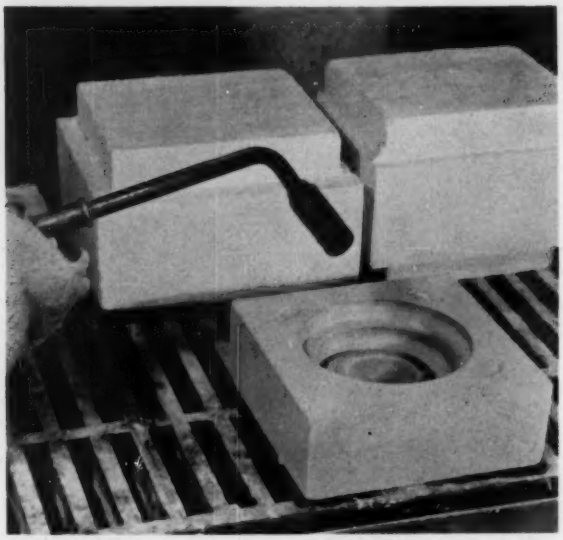
Mold Stripping. For small molds a gel time of about one min is convenient while for larger molds requiring longer mixing time, a gel time of about five minutes would be more suitable. As the gelling process progresses the mold slurry solidifies passing through the tough, rubber-like phase already mentioned. The mold is stripped from the pattern while in the rubbery condition making possible the use of patterns with no draft and in some cases with a slight undercut.



In Fig. 4 the mold has gelled and is stripped off the master pattern. The mold goes through a rubbery stage during gellation and should be permitted to attain the consistency of hard rubber prior to stripping to eliminate distortion.

Mold Firing. Reference to the above equation of the gelling process shows that a product of the reaction is alcohol and this together with the alcohol already in the binder medium produces a mold piece in the rubber-like condition which can be rapidly fired by igniting the alcohol.

Figure 5 shows the removal of alcohol by firing. The stripped mold has been set afire. This rapidly removes the alcohol, part of which is added in the manufacture of the binder, and part resultant from the hydrolysis of the ethyl silicate.



The volume change in the gel arising from the removal of the alcohol is accommodated by the system of cracks producing a mold cavity of exactly the same dimension as the pattern. To ensure this dimension stability the mold piece must be fired immediately on removal from the pattern.

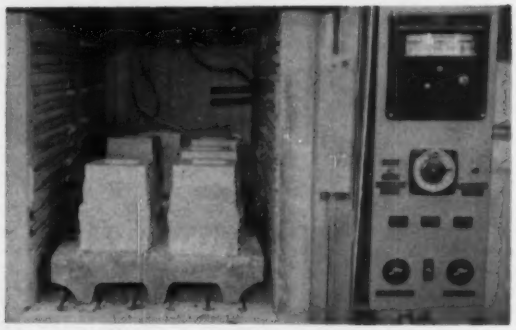
The rapid removal of alcohol by firing gives rise to a mold surface which is covered in a fine system of micro craze cracking. This crazing is progressive, the surface system of cracks provides an outlet for the alcohol beneath the surface. This liberation sets up further cracking, thereby releasing more alcohol, until the center mass is dry. It is important to ensure that the alcohol liberated at all faces of the mold piece is ignited.

The system of surface cracks is so fine however that no metal penetration occurs on pouring the mold, the smoothness of the casting surface being unimpaired. Should the surface crazing become too coarse, metal penetration may occur with consequent roughness on the casting surface. To ensure the desired fineness of surface crazing close adherence to the specified filler grading and binder medium composition is essential.

Mold Baking. When all traces of free alcohol have been removed in the firing operation, the mold piece is transferred to a baking oven and heated up to a temperature of 1800-2000 F, in order to complete the dehydration of the gel. The rate of heating is unimportant, due to the unique thermal characteristics of the mold material. Sufficient time must be allowed at temperature for complete removal of the combined alcohol and water. A useful guide is one hr/in. of cross-sectional thickness.

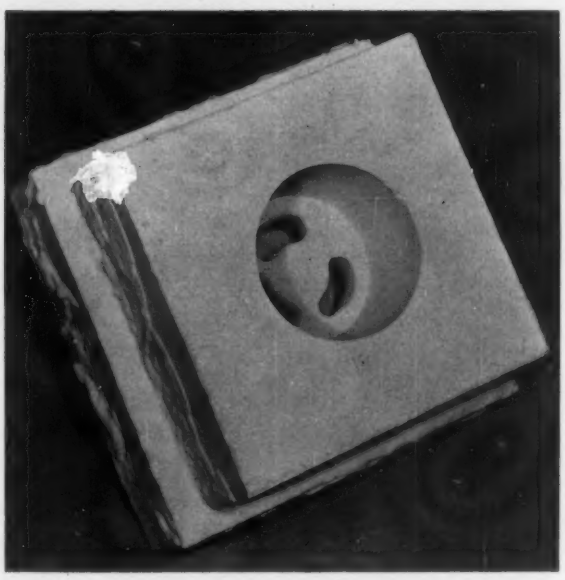
The atmosphere of the oven should be slightly oxidizing. A strongly oxidizing atmosphere, or a reducing atmosphere may cause trouble. It is essential that the floor of the oven is flat, as all refractories soften at high temperatures and the mold piece will take the shape of an uneven hearth. The mold piece may be cooled in the oven, or removed and cooled in still air. Figure 6 shows the mold in the furnace to be baked at 1800-2000 F to remove all traces of combined alcohol and water.

Mold Assembly. After baking, the mold sections should be carefully inspected before assembly. The assembled mold components as well as cores suitably clamped can now be cemented together. A variety of these luting techniques are used. With



large molds, in which the pressure of the liquid metal during pouring is high, dependence should not be placed entirely on the external luting of the mold pieces to prevent molds bursting at the joint. Such molds should be clamped or when the mold joint is horizontal, suitable weights may be applied to the top part, to counteract liquid metal pressure. Large molds should be contained in flasks.

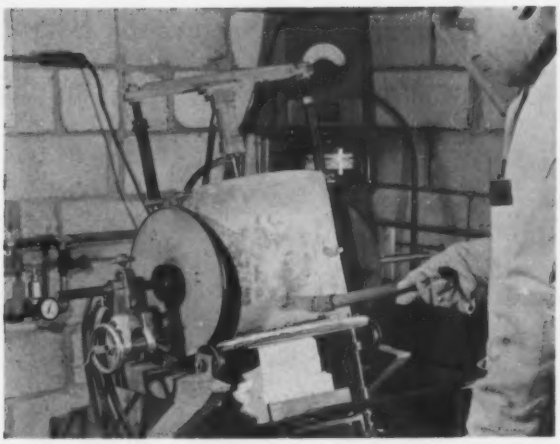
Figure 7 shows the final mold completely dimensionally stable, resistant to thermal shock and ready to receive the



charge of metal. When the design of the casting requires a hot mold so that, say fine detail may be reproduced, the cold mold can be placed directly into a hot mold heating oven and rapidly heated without any risk of mold damage by cracking or spalling of the surfaces. This heating of the mold has no significant effect on the dimensions of the mold cavity. All that happens during heating is that the fine cracks close up a little.

Casting. In many instances the mold may be poured as in normal sand casting practice. However, when small steel castings are being made it can be advantageous to use the technique developed for the lost wax process, in which the mold is clamped on the top of a small indirect arc or high frequency furnace, which contains an accurately weighed molten charge of the alloy to be cast, the furnace assembly being inverted the molten alloy flows from the furnace to the mold. Figure 8 shows a mold cast on a small indirect arc furnace.

As previously stated, the molds can be cast at room temperature, or if the alloy or shape of part warrants it, the mold may be heated to temperatures up to 2000 F. As already pointed out, due to the resistance of the mold to thermal shock, slow preheating of the mold is unnecessary, the mold



being charged directly into the hot furnace. The ability of the mold to be so heat treated quickly, speeds up the process considerably.

A further advantage of the crazed mold structure is that it is permeable, and a mold so produced requires no artificial venting. It will be evident that the final binding of the fired mold is purely mechanical. To obtain this interlocking, the grading of the filler must be controlled within the specified range and what is equally important the shape of the particles must be rough and angular.

Water washed or air blown sands are quite unsuitable since the roundness of these grains does not give interlocking, accordingly molds made with such fillers are weak after firing. The desired grain shape is usually obtained by crushing coarser material.

Finishing Operations. When the mold is cold, the refractory is broken away and the cast assembly blasted with 180 grit alumina. When intricate cored passages are in the castings and the alloy allows it, the refractory can be readily removed by treatment for a short while in a bath of molten caustic soda.

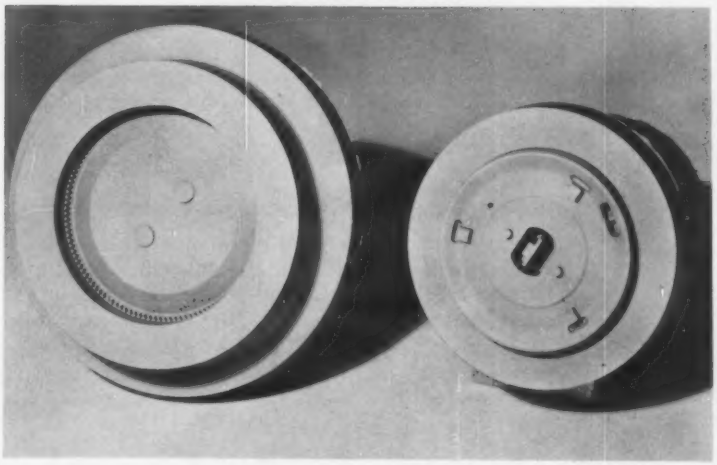


Figure 9 shows castings in the "as cast" condition. Note fidelity of detail and sharp corners.

Finished Casting. The gates are cut off by conventional methods depending on the alloy of the casting, and the gate area finished by grinding.

There are two major fields of application for this process: The first one is in the production of precision castings of the highest quality for the aircraft, missile, pump, chemical and food industry and the general foundry field where extremely accurate, smooth surfaced, large precision castings are required (Figs. 10-13).

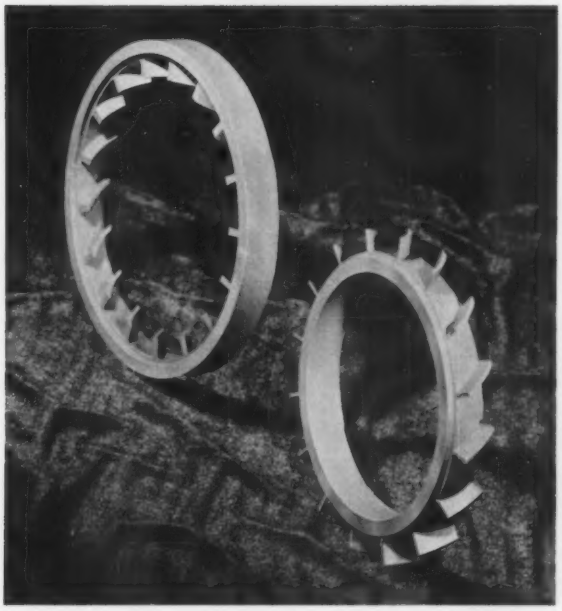


Fig. 10 — Automotive supercharger turbine wheels.

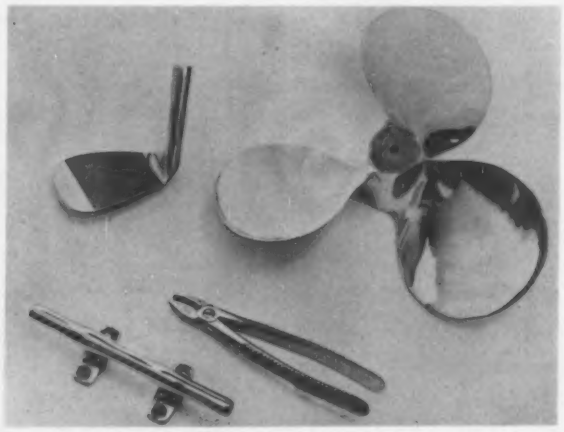


Fig. 11 — *Top left* — golf club head; *top right* — boat propeller; *bottom left* — boat cleat; *bottom right* — forceps.

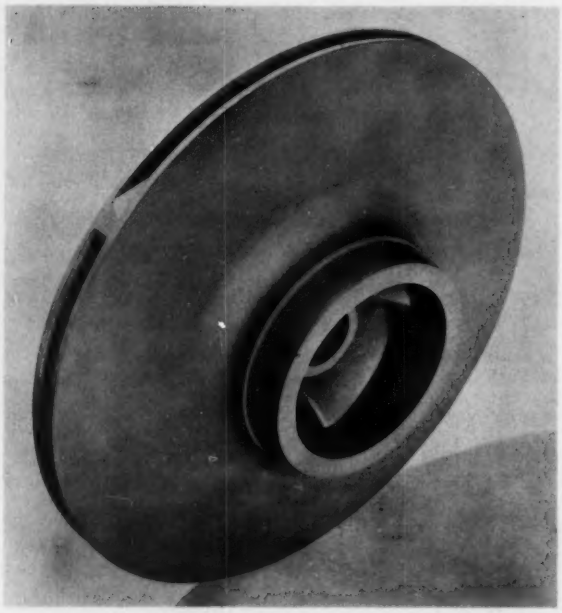


Fig. 12 — Double shrouded pump impeller in stainless steel.

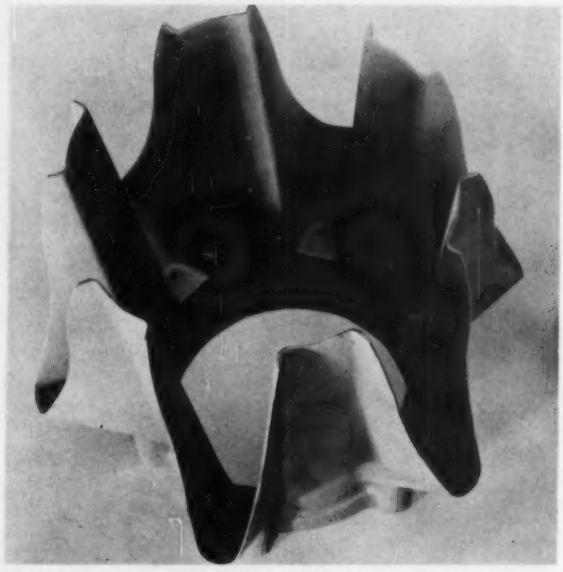


Fig. 13 — Reheat stabilizer body with 0.040 in. wall thickness.

The second field is the production of tools, dies and patterns, which would normally be completely machined. These fall into the following categories: foundry patterns and core boxes, die casting and permanent mold dies, drop forging and press forging dies, extrusion dies, plastic injection and compression molds, rubber molds, glass molds, stamping and forming dies, hobs, and a wide variety of miscellaneous tools, dies and cutters (Figs. 14-21).

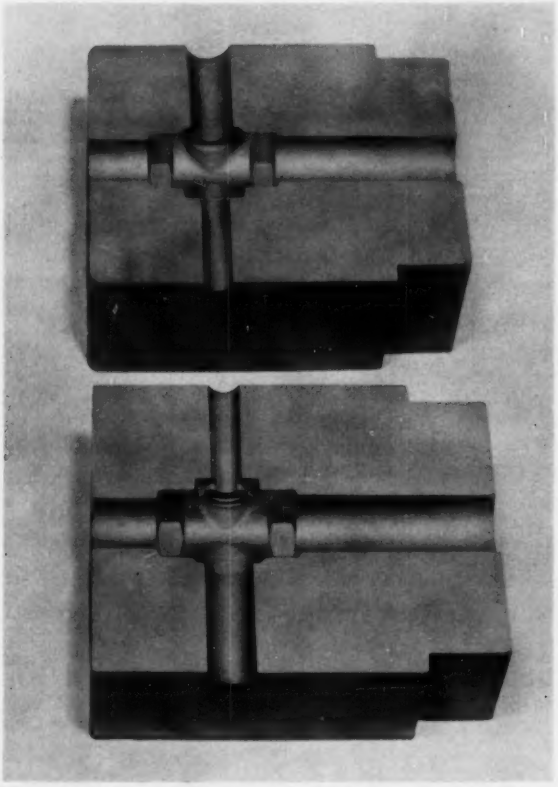


Fig. 14 — Forging dies — cast by Shaw process in hot work tool steel (H-12).

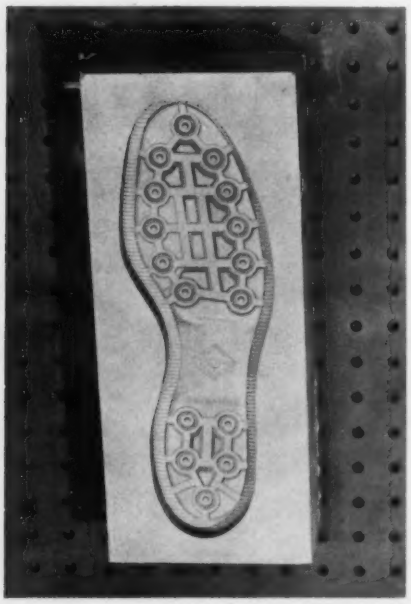


Fig. 15 — Rubber mold cast in air hardening tool steel.

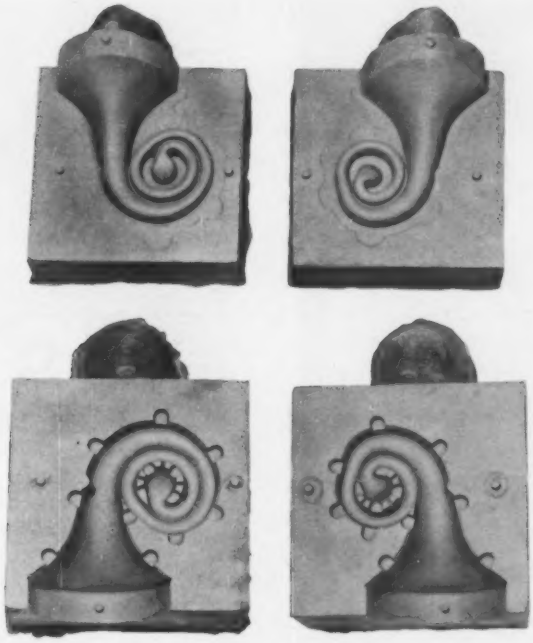


Fig. 16 — Die casting die inserts for automotive horn cast in hot work tool steel (H-13).

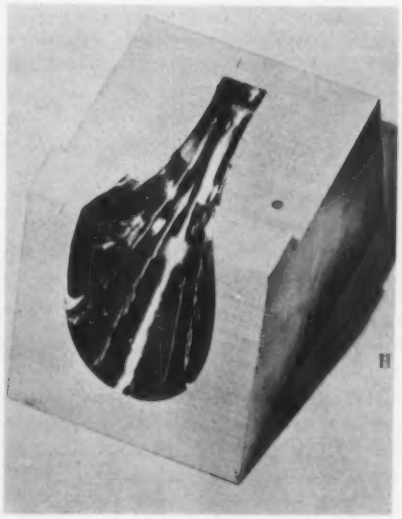


Fig. 17 (left) — Plastic mold insert for shoe heel in oil hardening tool steel (01).

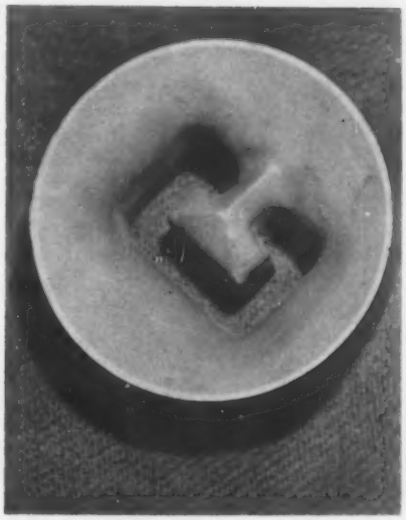


Fig. 18 (right) — Extrusion die in high speed steel Shaw casting.

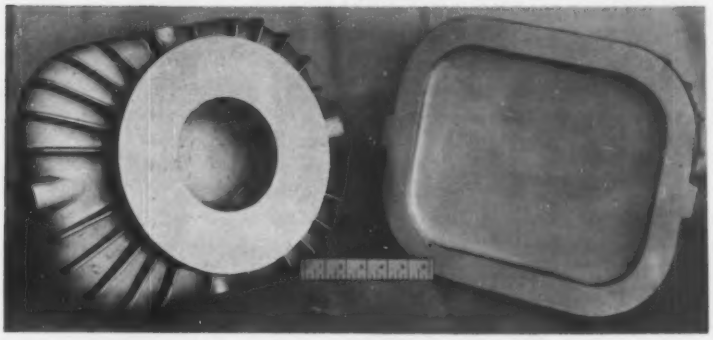


Fig. 19 — Stainless steel mold for television glass tube. Back face and core are of sand.

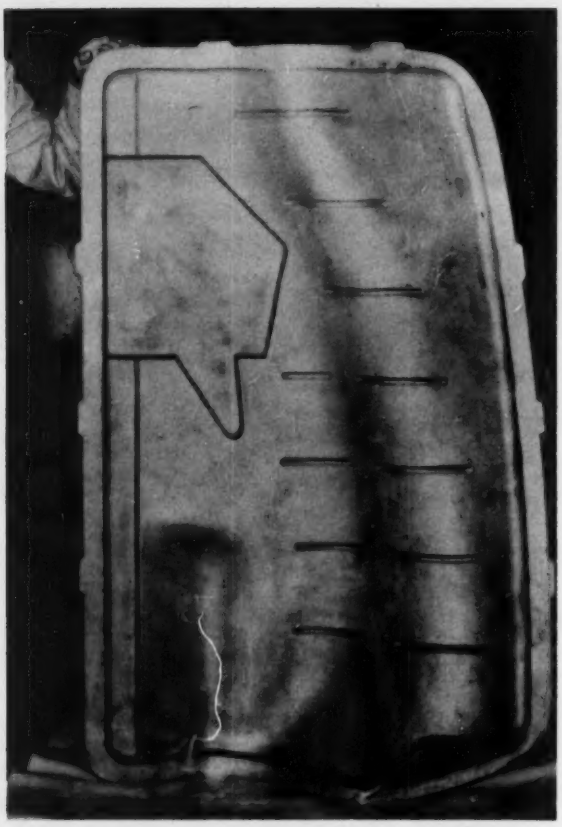


Fig. 20 — Stamping die for automotive panel, die cast in high carbon steel.

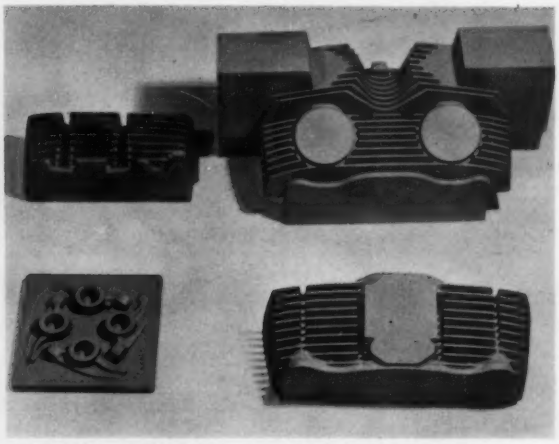


Fig. 21 — Foundry patterns cast in iron.

PART 2 — PRODUCING PATTERNS UTILIZING SHAW CASTINGS

This section will be confined to the reason the author's company selected the Shaw process, the application of the process to work and the results of the work with the process.

Throughout the years the pattern industry has made many contributions to maintaining the most economical tooling cost for the foundry industry. Today this is a formidable task in the face of increasing labor costs and the more involved pattern requirements of the foundry brought about by increased mechanization and every changing new production processes, such as shell molding. As new processes and techniques are available, the patternmaker has tried them, and if they have been applicable and economically sound they have taken their place as tools of the industry.

Today, one finds in everyday use in the pattern shop plaster materials of many types, including expanding and metal casting plasters, plastics from adhesives and cohesive materials to epoxy laminates and epoxy castables; machine tools such as mills, duplicators, die millers and, in some cases, jig borers and electrical discharge machines. The pattern shops also are using oil soluble bentonites, CO_2 cores, plaster or pressure casting and electro forming. The pattern industry has made its contribution to the state of our present day modern foundry industry.

In order to counteract the increasing cost of foundry tooling, experimentation with and the use of many of the materials and methods described above has been followed. It was this desire that prompted the evaluation of the Shaw process as one of several methods of casting more accurately, which it was felt would lead to the use of more cast to size areas of pattern castings. The problem of cost saving was made more important at this time by the wider use of permanent molds and shell core boxes. Both of these processes have required sounder castings of iron and more expensive tooling.

PRINCIPAL CHARACTERISTICS

The Shaw process was selected because of many advantages, as presented in part 1 of this paper. The principal characteristics from the author's company's point of view are:

Surface Finish. Exceptional surface finishes are possible with the process. Wood grain, center lines and any intricate details are readily reproducible.

Dense Metal Structure. Accompanied by good foundry practice the absence of gas producing elements, the natural venting and the insulating properties of a Shaw mold make dense metal possible. This is most advantageous in permanent molds and shell mold core boxes and patterns. In the case of aluminum, where a casting may be adequately risered the casting can be made free of the porosity encountered in pressure casting.

Regarding this point, the design of some castings, such as match plate castings, makes them impossible to adequately feed without scarring with risers. As a consequence, the pressure casting process is used. In this process the metal is injected into the mold at relatively low temperatures and the porosity found in this type of casting is an essential part of dimensional control and surface finish. To the company's knowledge, there is no better method of making castings of this kind. In aluminum, the configuration and

design of some castings make them difficult to cast by any other method than pressure casting.

Dimensional Control. This factor is probably better than any other process, because of the stability of the mold, the collapsibility, and other factors. The principal problem in any process, including lost wax, permanent mold and even die casting, is predicting the shrinkage. Predicting shrinkage is an art, and practice in the art of casting to zero tolerance is relatively new. This is the area where experience only will give results.

Presently, the company's tolerances range from ± 0.005 on 0 to 3 in., ± 0.015 on 3 to 8 in., ± 0.030 on 8 to 15 in. and ± 0.045 above this.

These tolerances sound wide open. However, it has been found that whereas duplicating machines are sold to hold ± 0.002 in., the workable tolerances are more in the range of ± 0.005 in. from model to finished part. In addition, most models are built using conventional wood patternmaking methods and, whereas it is possible to hold better than ± 0.015 in. tolerances, it is not generally good practice to depend on it. Most pattern shops have the practice of assuming that duplicating is adequate on irregular surfaces and consequently these areas are seldom checked.

Dimensional tolerances are approximately the same as possible in pressure casting.

Absence of Case Hardness in Iron. A useful and still seldom discussed advantage of a Shaw casting in iron is the almost total absence of surface hardness in the casting. The insulating properties in the mold are such that soft metal is encountered just below the surface. This makes nominal finish allowances possible.

Pattern Coating. Requirements of the Shaw process are different than other methods. A principal ingredient of the investment slurry is alcohol. Therefore, special coatings are required. The author's company has a coating system that works well at the present time, and continued work will give still better coatings in the future.

The Shaw Foundry

The prime consideration in the selection of equipment for the type of foundry necessary to produce pattern castings was flexibility. Generally, whereas there is no size limitation to a Shaw casting, the process had been confined to relative small castings. The Company's desire to produce large, as well as small castings, made it desirable to design and build a bake out furnace of the hearth type that will accommodate a mold 36 x 48 x 72 in. The mold making facilities are of the jobbing foundry type. Large as well as small molds can be made.

Metal melting also required versatility. As a consequence, high frequency induction is the most logical method. This enables the pouring of small as well as large heats of any metal. Induction melting also makes it possible to control analysis as well as temperature. Both are necessary to hold dimension. The furnaces used are one 30 lb, one 100 lb, one 300 lb and one 600 lb.

The cleaning facilities are much the same as found in any small jobbing foundry, with the exception that many gates and risers are sawed off.

Where to Apply the Process

The decision to apply the Shaw process should be made in each case on the basis of its merits as compared to many other methods such as duplicating, die milling, hobbing and others. The element of cost should include the consideration that by using the process a large part of the initial cost is not repetitive if more than one set of equipment is required. The evaluation of the method used in building a tool should be done on the basis of 1) dimensional tolerance requirements, 2) delivery advantages and 3) cost.

Pictured in Figs. 22-28 is equipment built using the Shaw process. They are presented in sequence of the most advantageous application to the more complex. The first utilizes, principally because of their dimensional requirements, the least machining and the greatest as-cast surfaces; the last, the most machining and the least as-cast surfaces. All of the applications pictured are acceptable tools for their use.

The ideal applications of the process are those such as Figs. 22, 23 and 24. On these, almost the entire configuration of the cavities was benched without machining. Machining was used only on the flat surfaces. In the case of the shell core box for the ports (Fig. 22), the parting of the box was extremely irregular. On this application the parting was cast to size and blued together.

Figure 27 is a permanent mold where the probability of many molds being required indicated that the use of the process was wise. On applications such as this, the procedure is:

1) A wood model of the cavity is made allowing for the two shrinkages; permanent mold shrinkage and Shaw process casting shrinkage.
2) An epoxy pattern is made by laminating over the model.
3) Sheet wax is added to areas requiring machining.
4) Shaw process casting is made.
5) The mold, core box or pattern is machined where necessary and finished by benching where possible.

There are many applications for permanent mold castings where reasonably open tolerances and permissible. In these cases, existing single shrink patterns can be used as models, and the Shaw casting of molds is a most economical method.

Figures 25, 26 and 28 picture complete pattern equipment where all but the plates and driers were cast in the Shaw process. In cases such as these, it has been the company's practice to make the larger pieces in two parts. The parts are splined and bolted together. This is done to minimize any inaccuracies encountered in the castings. On applications of this type, the pattern castings are laid out so that the cast surfaces of the irregular configuration can be used without machining. Machining is done to bring these areas into the proper position.

In the case of Figs. 27 and 28, the core boxes

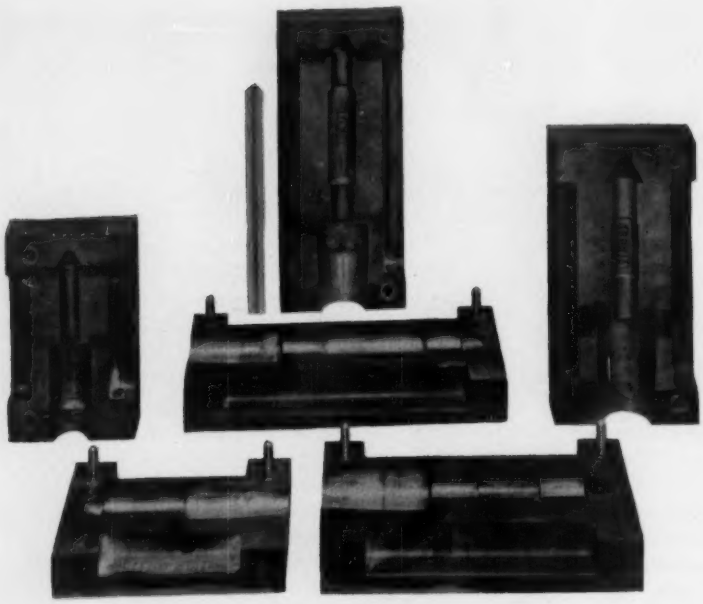


Fig. 22 — Shell core boxes for bolt cores. Core boxes are used on the heated platen type shell core machine. Boxes are solid and Shaw process cast iron. Machining was confined to partings and back of box.
(Courtesy International Harvester Co.)

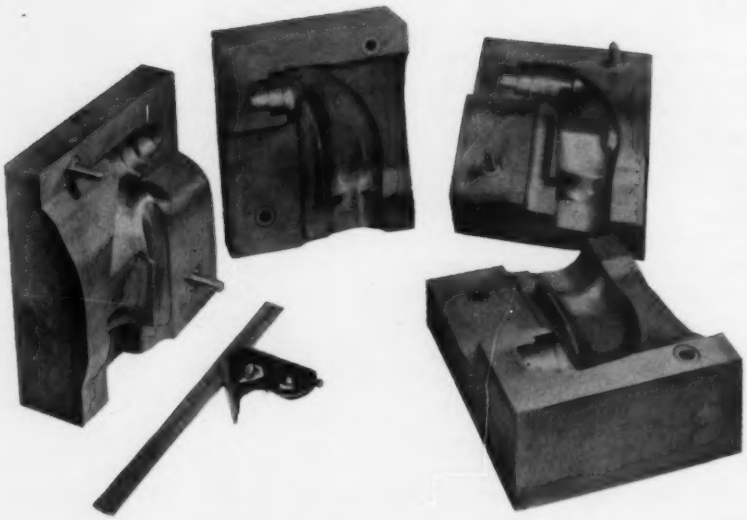


Fig. 23 — Shell core box for port cores. Core boxes are used on heated platen shell machine. Boxes are of solid and Shaw process cast iron. Machining was confined to the back and sides. The cavity and parting were hand finished.
(Courtesy International Harvester Co.)

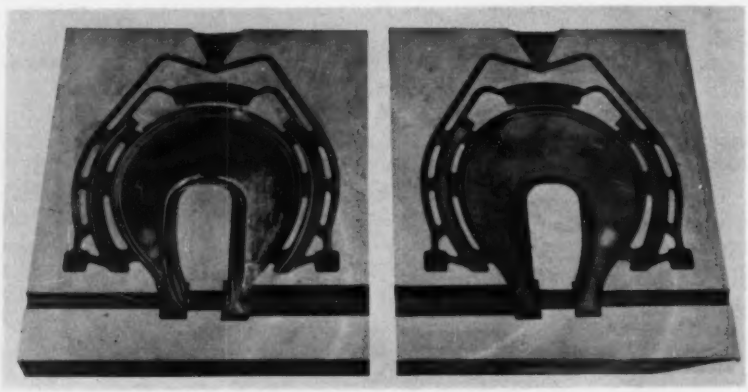
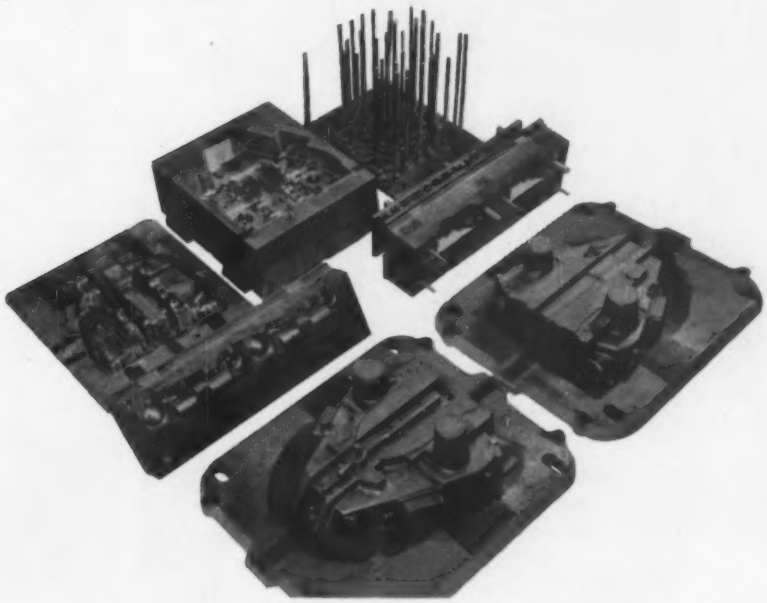


Fig. 24 — Permanent mold halves. Molds are mounting in an operating mechanism. These molds are solid heat resistant alloy cast iron made by Shaw process. Machining was confined to the flat faces and the round core pull slide.
(Courtesy Aluminum Casting and Engineering Co., Milwaukee)



Figs. 25 and 26 — Complete shell mold pattern equipment. Patterns, core boxes and mandrels are of cast iron made using Shaw process. Core box covers, ejector plates and pins of steel. Machining was done on all flat surfaces.

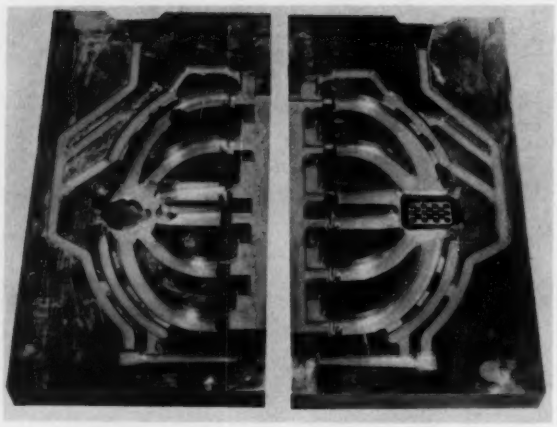


Fig. 27 — Permanent mold halves for aluminum manifold. Molds are made by Shaw process in cast iron and are approximately 16 x 31 x 2½-in. thick. The mold inserts are H-13 castings. Machining was done in the area of core prints, some sections of the pipes and the flat faces.
(Courtesy Chrysler Corp.)

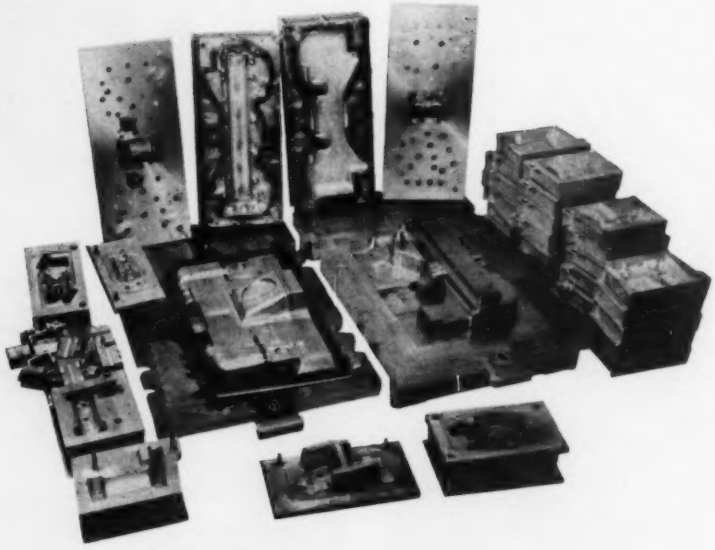


Fig. 28 — Complete sand pattern equipment. Patterns are of cast iron inserted in iron plates. Core boxes are of aluminum. Patterns and core boxes were cast in Shaw process. Machining was used on all flat surfaces.
(Courtesy International Harvester Co.)

were of the blown shell type. Core boxes of this kind require that a solid mandrel be built to lighten out the shell core. Mandrels of this type are excellent application because Shaw patterns for the mandrels can be made of plaster. The plaster patterns are easily made by pouring into the master pattern for the core box after the shell thickness has been lagged into the master.

Methods, such as described above, are being experimented with in fields other than the foundry. The author's company has furnished castings for forming dies, compression molds, injection molds, die casting dies and cores, and several large companies are evaluating the process for forging dies. In addition, these methods can be applied to glass molds, coining dies, straightening dies, and many other tooling applications. The wider use of castings for tooling in fields other than foundries are markets for the patternmaker and foundryman.

The Shaw process has given the author's company what is believed to be the best casting attainable by any method. The process, however, covers the mold structure only. The other elements of making a casting—the gating, metallurgy and patternmaking—must all be done correctly to assure a successful casting. It is believed the increased use of precision casting has a tremendous future for the patternmaking and casting industry as a whole.

It behooves the industry, therefore, to refrain from jeopardizing that future by misapplying castings where other methods are more suited.

CONCLUSION

Precision casting is the most promising new method on the horizon today for the building of tools for the foundry as well as many other industries. Presently there are many applications for precision castings in the tooling field where reasonably open tolerances can be sold with substantial savings in tooling cost. In addition, some savings are presently attainable on patterns requiring close tolerances by machining to varying degrees. Through improvement in the techniques of precision casting, more durable and economical tooling will be available to industry and many new uses for castings will be opened as markets for the foundry industry as a whole.

VACUUM INDUCTION MELTING HIGH STRENGTH STEELS

by P. S. Schaffer, P. J. Ahearn and M. C. Flemings

ABSTRACT

General quality improvements are made in high strength steel castings by the application of vacuum induction melting techniques. Theoretical considerations of crucible-melt reactions, deoxidation, desulfurization, degassification, dissociation and volatilization are applied to the conduct of vacuum heats. Appreciable reduction in residual gas content and size and frequency of nonmetallic inclusions is obtained. This reduction results in increased ductility and toughness, especially at the ultra high strength levels, over steel castings produced by conventional air melting methods.

INTRODUCTION

Production of superior quality utra high strength steels in vacuum requires that the metallurgist understand the thermodynamics and kinetics involved in steelmaking reactions, and the effect of reduced pressure on these reactions. Accordingly, let us examine the advantages of vacuum induction melting, first in a general way and then specifically in regard to the important chemical reactions controlling steel quality.

Vacuum processing of steel results in a reduction of residual gas content and improved cleanliness, for the only possible contaminating reaction is from the crucible. Lowering of gas content is derived from the inductive stirring mechanism which continually exposes new surfaces of molten metal to vacuum, and thus facilitates mass transfer of gaseous elements in solution to their gaseous states by desorption.

Oxygen is reduced to extremely low levels by the carbon boil, at which time atomic hydrogen and nitrogen diffuse into the carbon monoxide bubbles, thereby causing further reduction of these deleterious gases. Thus, reactions involving the precipitation of oxides and nitrides from the melt are not favored, since the gas content is extremely low.

Other improvements that can be derived from utilizing vacuum technology in steelmaking are as follows. Vacuum prohibits formation of slag over the melt; therefore, slag-type mechanical inclusions are completely absent from the castings. Composition can be closely controlled by minimizing losses of reactive elements due to oxidation and control of high vapor pressure alloying elements. Greater uniformity in mechanical properties should be obtained due to less absolute segregation of gaseous elements in solid solution. Detrimental volatile impurities can be removed by distillation.

The combined effect of lower residual gas content, reduction in size and frequency of nonmetallic and mechanical inclusions, close composition control, less absolute gaseous segregation and removal of detrimental volatile impurities should result in superior mechanical properties, especially at high strength levels where slight imperfections create severe stress concentration effects.

The following is a detailed account of the theoretical aspects, experimental procedures and results obtained by vacuum and controlled atmosphere melting, refining and casting of high strength steels to yield low residual gas content and improved cleanliness.

VACUUM MELTING THEORETICAL CONSIDERATIONS[1]

Crucible-Melt Reactions Thermodynamics[2,3,4]

The selection of an optimum crucible material for vacuum induction melting of steel is dependent upon the ability of the crucible to withstand any tendency for the following reaction to occur.

$$M_xO_y \text{ (crucible)} + y\underline{C} \text{ (solution)} = x\underline{M} \text{ (solution)} + yCO \text{ (gas)} \qquad (1)$$

This type of reaction becomes more favorable as pressure is reduced, and is the most important consideration in the selection of a refractory oxide crucible.

Consider a magnesia (MgO) crucible and make these assumptions: a) neglect the effect of alloying elements in the steel; that is, consider it to be pure iron; b) use weight per cent of elements in solution instead of activity – an error of less than ± 10 per cent will occur; c) P_{CO}, the partial pressure of carbon monoxide, may be considered equal to the total pressure in the vacuum chamber; d) the existing conditions during refining of the steel are: a partial pressure of CO (chamber pressure) above the molten bath of 10^{-5} atmospheres (7.6 microns), metal temperature of 1600 C (2912 F, 1873 K) and a carbon content of 0.40 weight per cent.

The reaction is:

$$MgO \text{ (crucible)} + \underline{C} \text{ (solution)} = Mg \text{ (gas)} + CO \text{ (gas)} \qquad (2)$$

P. S. SCHAFFER and P. J. AHEARN are Met., Rodman Laboratory, Watertown Arsenal, Watertown, Mass. M. C. FLEMINGS is Asst. Prof. of Met., Massachusetts Institute of Technology, Cambridge.

(This paper is based on a thesis submitted by Philip S. Schaffer in partial fulfillment of the requirements for the Degree of Master of Science, Dept. of Met., Massachusetts Institute of Technology.)

$$\Delta F^\circ_{(2)} = \Delta H^\circ - T\Delta S^\circ = +140{,}090 - 55.62T = +35{,}890 \text{ calories} \quad (3)$$

$$\Delta F^\circ = -R\,T\ln k = -4.575\,T\log K \quad (4)$$

$$K_{(2)} = \frac{P_{Mg}\,P_{CO}}{(a_{\underline{C}})} = \frac{P_{Mg}\,P_{CO}}{(\%_o\underline{C})} \quad (5)$$

where

ΔH° = standard enthalpy change of the reaction.
ΔS° = standard entropy change of the reaction.
T = temperature in degrees Kelvin.
ΔF° = standard free energy change of the reaction.
P_{Mg} = partial pressure of magnesium gas.
P_{CO} = partial pressure of carbon monoxide gas.
$a_{\underline{C}}$ = activity of carbon in solution.
$\%_o\underline{C}$ = weight per cent of carbon in solution.
$K_{(2)}$ = equilibrium constant for reaction (2).

A reaction is not favored to proceed to the right when the standard free energy change is positive, but under the vacuum conditions, where the gaseous products are continuously being pumped away, the reaction becomes favorable to proceed to the right, as given by the applicable equilibrium constant K.

$$\log K_{(2)} = -\frac{\Delta F^\circ}{(4.575)\,(1873)} = -\frac{(140{,}090 - 55.62[1873])}{(4.575)\,(1873)} = -4.19 \quad (6)$$

$$K_{(2)} = 6.45 \times 10^{-5} = \frac{P_{CO}\,P_{Mg}}{(\%\,\underline{C})} \text{ @ } 1600\,C \quad (7)$$

$$P_{CO}\,P_{Mg} = (6.45 \times 10^{-5})\,(0.40) = 2.58 \times 10^{-5} \text{ atm.}^2 \quad (7a)$$

Now assume $P_{CO} = P_{Mg}$, then $P_{CO} = P_{Mg} = 3.86$ mm. This means that when the partial pressure (chamber pressure) of carbon monoxide in the system is below 3.86 mm, at 1600 C, carbon in the steel may react with the MgO crucible, as shown in reaction (2), producing Mg vapor and CO gas which are continually removed from the vacuum chamber.

Similar calculations for other possible crucible materials illustrate that of the common refractory oxides, lime yields the lowest partial pressure of carbon monoxide, indicating the least tendency for the melt-crucible reaction to occur. However, due to its hygroscopic property; that is, its tendency to absorb and retain moisture, it is not desirable for use in vacuum melting applications, and magnesia becomes most applicable. Table 1 is a list of equilibrium partial pressures of carbon monoxide above the steel melt (at 1600 C) in order of increasing pressures involved in melt-crucible reactions in vacuum induction melting of high-strength steels.

TABLE 1 — PARTIAL PRESSURE OF CARBON MONOXIDE IN MELT-CRUCIBLE REACTIONS

CaO (lime)	$P_{CO} = 0.68$ mm, Hg
MgO (magnesia)	$P_{CO} = 3.86$ mm.
ZrO_2 (zirconia)	$P_{CO} = 4.11$ mm.
Al_2O_3 (alumina)	$P_{CO} = 16.90$ mm.
SiO_2 (silica)	$P_{CO} = 1.95$ atm.

Considering only the thermodynamics involved in the melt-crucible reactions, and eliminating CaO due to its hygroscopic tendency, MgO is best suited for vacuum induction melting of high-strength steels, as a partial pressure of CO of 3.86 mm or less need be obtained in order for the melt-crucible reaction to occur. SiO_2 would be the least desirable to use as a partial pressure of CO of 1.95 atm or less need be reached for the reaction to be favorable.

Also, the application of vacuum will prevent reaction (1) from attaining equilibrium as the gaseous product CO is continually removed from the system, thereby making the

$$M_xO_y\,(\text{cruc.}) + y\underline{C}\,(\text{soln.}) = x\underline{M}\,(\text{soln.}) + y\,CO\,(\text{gas}) \quad (1)$$

reaction favorable to proceed to the right as written, so that the oxide crucible is continually reduced by the carbon in solution at a given pressure and temperature.

Thermodynamics of Deoxidation

Oxygen participates in every method of steel production, and its concentration in the molten metal greatly determines the rate and completeness of the refining process. During the oxidation stage of the cycle, the oxygen content of the melt is determined by its carbon content which generally is higher than in the carbon-oxygen equilibrium.

Deoxidation of molten steel in vacuum can be achieved by the addition of elements that form oxides of greater stability and lower solubility than that of the dissolved oxygen in the steel bath.

Carbon and hydrogen can react with the oxygen in the steel bath, forming gaseous products which can be continuously pumped away until equilibrium is reached or approached, while adding oxide-forming elements tends to form oxides which are insoluble in the solid state and therefore precipitate as nonmetallic inclusions during solidification.

Deoxidation with a solid or gas that forms a solid or liquid oxide is not affected by reduced pressure, but if a gaseous oxide is formed, then lowering the pressure will increase deoxidation if more moles of gaseous products are formed than moles of gaseous reactants or if the reactants are liquid or solid but the product is gaseous.

Examples of such reactions are:

$$MO_3\,(\text{solid}) + 3\,H_2\,(\text{gas}) = \underline{M}\,(\text{solution}) + 3\,H_2O\,(\text{gas}) \quad (8)$$

$$\underline{M}\,(\text{solution}) + \underline{O}\,(\text{solution}) = MO\,(\text{gas}) \quad (9)$$

Reaction (8) is not favored by reduction in pressure as three moles of gaseous reactant are needed to produce three moles of gaseous product. Reaction (9) is driven further to the right by application of vacuum because the gaseous product can be continuously removed so equilibrium will not be attained.

Deoxidation with carbon. The equilibrium constant for the deoxidation reaction of molten iron by carbon is expressed:

$$\underline{C}\,(\text{solution}) + \underline{O}\,(\text{solution}) = CO\,(\text{gas}) \quad (10)$$

$$K_{(10)} = \frac{P_{CO}}{(a_{\underline{C}})\,(a_{\underline{O}})} \quad (11)$$

at a carbon content of less than one per cent, weight

per cent may be substituted for activity so equation (11) can be written:

$$K_{(10)} = \frac{P_{CO}}{(\%\underline{C})\,(\%\underline{O})} \qquad (12)$$

The equilibrium constant K is a function of temperature only; therefore, at a given temperature, the application of vacuum reduces the value P_{CO} which in turn lowers the (% C) (% O) product. That is, for a given value of % C, a lower oxygen content can be obtained; therefore, the deoxidation power of carbon is increased.

Melting a steel containing 0.40 weight per cent carbon, at a pressure of 10^{-5} atm (7.6 microns), assuming carbon monoxide is the only gas present in the system, at a temperature of 1600 C (1873 K), we obtain:

$$\Delta F^{\circ}_{(10)} = -8510 - 7.52T \qquad (13)$$

$$\log K_{(10)} = \frac{-(22{,}600)}{-(4.575)\,(1873)} = 2.637 \qquad (14)$$

$$K_{(10)} = \frac{P_{CO}}{(\%\underline{C})\,(\%\underline{O})} = 434 \qquad (14a)$$

$$\%\underline{O} = \frac{(10^{-5})}{(0.40)\,(434)} = 5.76 \times 10^{-3} \text{ wt. per cent} \qquad (14b)$$

Therefore, the equilibrium oxygen content is 5.76×10^{-3} weight per cent at 1600 C with 0.40 per cent carbon in solution at a partial pressure of carbon monoxide of 10^{-5} atmospheres.

It has been found that the deoxidation power of carbon is less than that calculated from the value of the equilibrium constant of the reaction. Samarin[5] found that at 1590 C, the change of the partial pressure of CO by a factor of 10^4 has no influence upon the deoxidizing power of carbon in molten iron in a magnesia crucible.

Several reasons can be offered for the deviation from theoretical values. Utilizing a magnesia (MgO) crucible during vacuum induction melting, it is found that carbon dissolved in steel may react with the refractory oxide expressed:

$$MgO\,(s) + \underline{C}\,(\text{soln.}) = Mg\,(g) + CO\,(g) \qquad (2)$$

The MgO is reduced to Mg (in solution); however, due to its great insolubility in steel and high vapor pressure it volatilizes to Mg (gas); and O (in solution), continually reacting with the carbon forming CO (gas), which are then pumped out of the system.

Kinetic factors in the deoxidation reaction must be taken into consideration, as actually a condition of "metastable equilibrium" exists. The carbon-oxygen reaction only approaches equilibrium and is a slow process.

Other reasons which may account for the deviation from theoretical results are: the carbon boil in the vacuum induction furnace does not represent true equilibrium conditions; therefore, the (%C) (%O) product is usually somewhat larger than calculated; carbon monoxide is not evolved as a pure gaseous compound, but is always accompanied by carbon dioxide; the use of weight percentages instead of activities can only be justified at low carbon contents.

Two possible sources and mechanisms of CO bubble formation are suggested.[6] Violent inductive stirring, by the development of vortices, may provide the energy to nucleate cavities in the melt into which the carbon monoxide may accumulate as a result of the surface reaction between the carbon and oxygen. Another nucleation source may exist in the cavities already present in the crucible at the crucible-melt interface.

If these cavities exist in such a form so as to prevent wetting of the cavity-crucible surface by the melt, then there will exist numerous nucleation sites at which carbon monoxide may accumulate. On the other hand, the evolution of CO from the melt may only occur if the gas bubbles overcome barometric pressure, hydrostatic metal head and surface tension of molten steel.

It can be concluded that it is a good assumption in determining the partial pressure of carbon monoxide to consider it equal to the total pressure in the vacuum chamber provided there is no furnace outgassing or atmospheric leaks into the system. The value of 5.76×10^{-3} weight per cent oxygen is the theoretical minimum that could be attained if only the reaction $\underline{C} + \underline{O} = CO(g)$ were involved; however, reduction of the magnesia crucible creates a source of additional dissolved oxygen.

Deoxidation with manganese, silicon and aluminum. When a metallic deoxidizing element is added to the steel bath, a chemical reaction occurs in which dissolved oxygen is removed from solution in the metal forming the oxide of the more active metal. Reduction in pressure during the refining period does not enhance deoxidation with solid oxide forming elements so carbon, aluminum, silicon and manganese in decreasing order are effective deoxidizers for use in vacuum induction melting of high strength steels. From equation (14b), it is concluded that if optimum refining time were utilized, carbon alone would be able to deoxidize the melt until the carbon-oxygen equilibrium is approached as closely as possible, providing no other reactions were involved.

Thermodynamics of Desulfurization

Low sulfur content of vacuum induction melted steels is primarily due to the use of an expensive, high-purity grade of raw materials with low residual sulfur content or remelting a master alloy produced in air utilizing conventional melting grade alloys, but desulfurized by one of various methods.

The ideal method to remove sulfur dissolved in molten steel in vacuum would be to form a gaseous sulfide having a high vapor pressure with sufficiently high negative free energy of formation, so that it could be pumped from the system.

In Fig. 1, the plot of standard free energy of formation of sulfides of interest in steelmaking reactions as a function of temperature, it is seen that low pressure and/or high temperature will facilitate dissociation of metal sulfides.

A line corresponding to a partial pressure of sulfur of 10^{-5} atmospheres is superimposed on the chart, which at the same operating pressure in the vacuum system is the limiting case. That is, the sulfide vapor is assumed to be the only gaseous substance present in the system. It is theoretically possible to dissociate

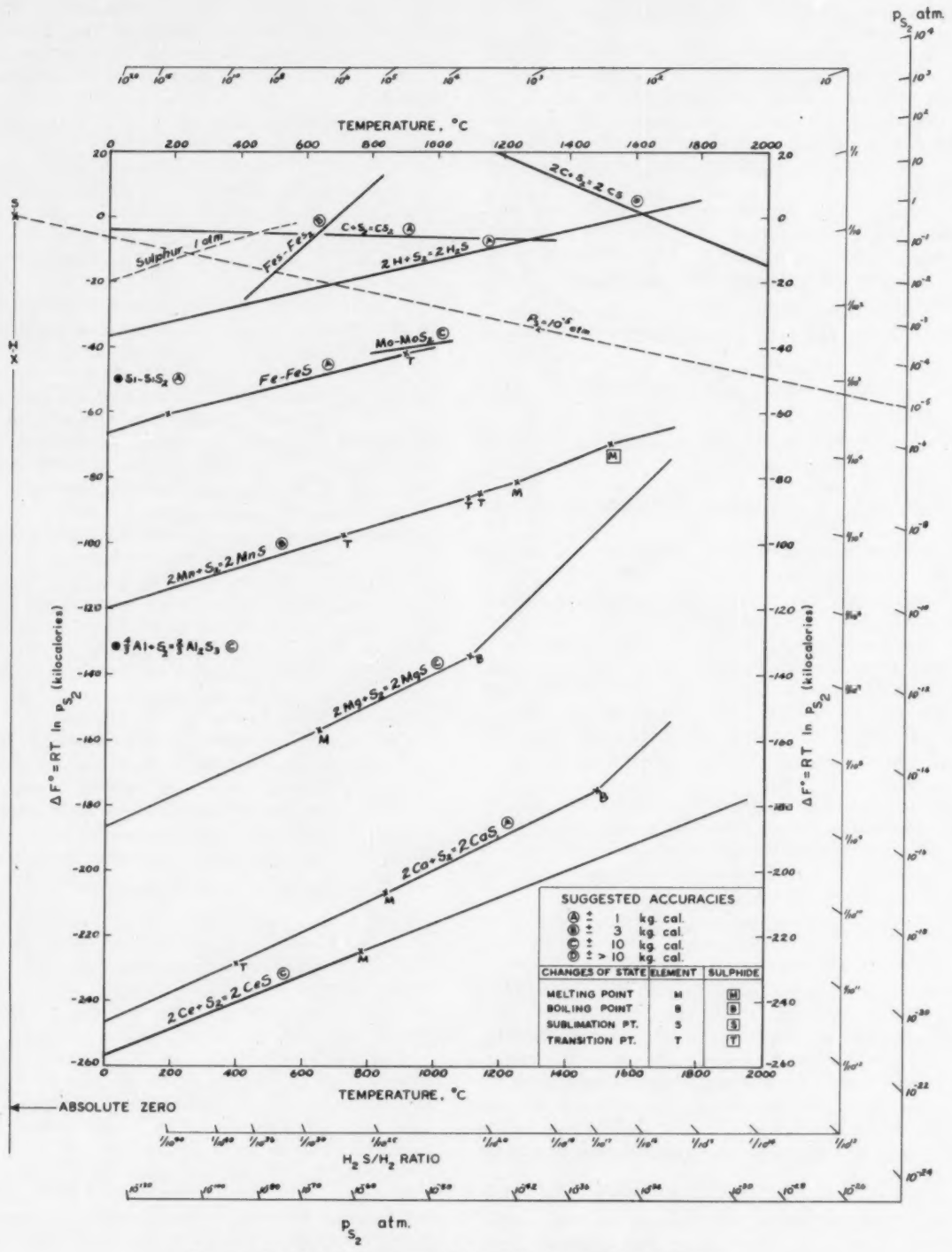


Fig. 1 — Standard free energy of formation for metal and gaseous sulfides of interest in steelmaking as a function of temperature.

any sulfide appearing above this line if it exists in its pure state; however, its behavior is somewhat different when dissolved in steel.

Thermodynamics of some of the possible reactions of desulfurization in which gaseous sulfides are produced using reactants already present in the molten steel were considered. Calculations were based on pure iron, neglecting the effect of the presence of other alloying elements which effect the activity of sulfur; that is, the concept of interaction parameters.

At low concentrations, weight per cent of element in solution is used in place of activity, yielding results within approximately 10 per cent of those using activity and interaction parameter. It was also assumed that the sulfide is the only vapor present in the vacuum system; that is, the partial pressure of the gaseous product equals the chamber pressure, which is only true in the limiting case.

The desulfurization reactions considered, and the resulting equilibrium partial pressures for these reactions, are presented in Table 2.

TABLE 2 — POSSIBLE DESULFURIZATION REACTIONS AND PARTIAL PRESSURES OF GASEOUS SULFIDES INVOLVED IN VACUUM MELTING OF HIGH-STRENGTH STEELS

Reactions	Weight per cent	Partial Pressures
$\underline{C}$ (soln.) + 2 $\underline{S}$ (soln.) = CS_2 (gas)	0.40 C, 0.020 S	$P_{CS_2} = 1.01 \times 10^{-8}$ atm
% $\underline{S}$ (soln.) = ½ S_2 (gas)	0.020 S	$P_{S_2} = 3.50 \times 10^{-9}$ atm
$\underline{C}$ (soln.) + $\underline{S}$ (soln.) = CS (gas)	0.40 C, 0.020 S	$P_{CS} = 4.20 \times 10^{-9}$ atm
2 $\underline{H}$ (soln.) + $\underline{S}$ (soln.) = H_2S (gas)	0.00005 H, 0.020 S	$P_{H_2S} = 9.85 \times 10^{-10}$ atm
$\underline{S}$ (soln.) + 2 $\underline{O}$ (soln.) = SO_2 (gas)	0.020 S, 0.0008 O	$P_{SO_2} = 1.41 \times 10^{-11}$ atm
$\underline{Si}$ (soln.) + 2 $\underline{S}$ (soln.) = SiS_2 (gas)	0.25 Si, 0.020 S	$P_{SiS_2} = 2.14 \times 10^{-12}$ atm

At gaseous sulfide partial pressure of 10^{-5} atm, which is the limiting case only at a chamber pressure of 10^{-5} atm, if the sulfide vapors are assumed to be the only gases present in the system, there will be no desulfurization obtained by carbon, hydrogen, oxygen, silicon or distillation of sulfur because the equilibrium partial pressures of the gaseous sulfides are less than their partial pressures (chamber pressure) above the melt.

Metallic desulfurizers, such as calcium, magnesium and rare earth elements have been studied; however, the disadvantage in using these lies in the necessity of a slag and the formation of solid sulfides which is undesirable in vacuum processing.

Degassification

The higher solubility of gases in liquid metal relative to the solid, provided the concentration exceeds the solubility in the liquid upon solidification, results in gaseous evolution and precipitation at the dendritic interstices causing embrittlement of the material. Degassing of molten steel in vacuum is controlled by inductive stirring and the carbon-oxygen "metastable equilibrium" deoxidation reaction.

Inductive stirring continually exposes new surfaces of molten metal to vacuum which facilitates mass transfer of gaseous elements in solution to their gaseous states by desorption. Deoxidation occurs mostly during the carbon boil, at which time the carbon monoxide bubbles are the controlling factor in the removal of gases in their atomic state. Hydrogen and nitrogen diffuse into the CO bubbles until the partial pressures of these gases in the bubbles are in equilibrium with the hydrogen and nitrogen in the melt.

In a stagnant system, that is, with the vacuum chamber isolated and an inert atmosphere of argon or helium introduced, equilibrium will be reached when the partial pressure of the gas in the metal equals the partial pressure of the gas in the inert atmosphere and no further reduction will occur. However, in a dynamic vacuum system, it is theoretically possible to reach extremely low gas concentrations, assuming no other gas producing reactions are occurring, as equilibrium is never attained because the gaseous products are continually pumped out of the chamber.

In the following calculations the partial pressure of the gas is assumed to be equal to the chamber pressure which in effect is the limiting case. Also, weight per cent is substituted for activity.

The solubility of diatomic gases in molten metal, at a given temperature is proportional to the square root of the partial pressure of gas in equilibrium with the metal, according to Sievert's Law:

$$\%\,\underline{Gas} = K\sqrt{P_{Gas_2}} \qquad (15)$$

Hydrogen dissolved in steel. Hydrogen dissolves in liquid iron as single atoms according to the reaction:

$$H_2\ (gas) = 2\,\underline{H}\ (solution) \qquad (16)$$

$$(K)^2_{(16)} = K' = \frac{(a_{\underline{H}})^2}{P_{H_2}} = (0.0027)^2 \text{ @ } 1600\,C \qquad (17)$$

so the per cent hydrogen that can exist in solution with molten iron at a partial pressure (assume partial pressure equals chamber pressure) of hydrogen of 10^{-5} atmospheres is:

$$\%\,\underline{H} = (0.0027)\ (\sqrt{10^{-5}}) = 8.45 \times 10^{-6} \qquad (17a)$$

Therefore, a a hydrogen content greater than 8.45×10^{-6} weight per cent (at 1600 C) gaseous evolution would occur.

At a hydrogen concentration of 0.0001 per cent (1 ppm):

$$P_{H_2} = \frac{(\%\underline{H})^2}{(K)^2} = \frac{(0.0001)^2}{(0.0027)^2} = 1.37 \times 10^{-3}\ \text{atm} = 1.04\ \text{mm} \qquad (17b)$$

the hydrogen pressure above the melt must be greater than 1.04 mm to prevent evolution of hydrogen gas, whereas at a hydrogen concentration of 0.00001 per cent (0.1 ppm) a pressure greater than 10.4 microns is needed.

$$P_{H_2} = \frac{(0.00001)^2}{(0.0027)^2} = 1.37 \times 10^{-5} \text{ atm} = 10.4 \text{ microns} \quad (17c)$$

Just below the solidification temperature of iron, it is found that with 0.0001 per cent dissolved hydrogen, the hydrogen partial pressure equals 11.9 mm whereas at 0.00001 per cent hydrogen, P_{H_2} equals 119 microns. This means that in order to prevent evolution of hydrogen gas at 1 ppm and 0.1 ppm concentrations at the solidification temperature a hydrogen partial pressure above the melt greater than 11.9 mm and 119 microns, respectively, is necessary.

Nitrogen dissolved in steel.

$$N_2 \text{ (gas)} = 2\,\underline{N} \text{ (soln.)} \quad (18)$$

$$(K)^2_{(18)} = K' = \frac{(a_{\underline{N}})^2}{P_{N_2}} = (0.040)^2 \text{ @ } 1600 \text{ C } (2912 \text{ F}) \quad (19)$$

The concentration of nitrogen that can exist in solution with molten iron at a nitrogen partial pressure of 10^{-5} atm is:

$$\%\,\underline{N} = (0.040)\left(\sqrt{10^{-5}}\right) = 0.000127 \text{ per cent} \quad (19a)$$

Therefore, evolution will occur at a nitrogen content greater than 1.27 ppm under the existing conditions.

In order to prevent gaseous evolution of nitrogen at a concentration of 0.0002 weight per cent, a partial pressure of nitrogen

$$P_{N_2} = \frac{(a_{\underline{N}})^2}{(K)^2} = \frac{(0.0002)^2}{(0.040)^2} = 2.5 \times 10^{-5} \text{ atm} = 19.0 \text{ microns} \quad (19b)$$

greater than 19.0 microns is needed. Just below the solidification temperature of iron, it is found that with 0.0002 per cent dissolved nitrogen, the equilibrium nitrogen partial pressure is 252 microns, which means

$$P_{N_2} = \frac{(a_{\underline{N}})^2}{(K)^2} = \frac{(0.0002)^2}{(0.011)^2} = 3.31 \times 10^{-4} \text{ atm} = 252 \text{ microns} \quad (19c)$$

that a partial pressure of nitrogen greater than 252 microns needs to be maintained above the melt to prevent evolution.

Dissociation

The dissociation of a compound into its elements, provided that at least one is gaseous, can be influenced by changing the pressure. Figure 2 is a plot of standard free energy of formation of oxides of interest in steelmaking reactions as a function of temperature. As the free energy of formation becomes more negative, the metal oxide is more stable; also it can be seen that low pressure and/or high temperature will facilitate dissociation of metal oxides.

A line corresponding to an oxygen partial pressure of 10^{-5} atmospheres is superimposed on the chart, which is for pure metals and oxides only. It can be concluded that in practice during vacuum induction melting of steel, oxygen is not removed by dissociation of metal oxides at an oxygen partial pressure above the melt of 10^{-5} atm. Possible exceptions are nickel oxide (NiO) and hematite (Fe_2O_3).

Superimposition of the carbon monoxide formation lines at pressures ranging from 10^2 to 10^{-6} atmospheres shows that reduction in pressure enables carbon to reduce all metal oxides at a lower temperature.

Many of the metal nitrides and hydrides will dissociate at a partial pressure of 10^{-5} atmospheres of nitrogen and hydrogen, respectively, at steelmaking temperatures; however, removal of these gases is probably accomplished by a combination of diffusion and dissociation.

Volatilization

Dissolved metals, having a higher equilibrium vapor pressure than their vapor pressure above the melt, will volatilize out of solution as a function of the temperature, vapor pressure, chamber pressure, composition and time.

This vaporization would be beneficial in melting if a high-purity material were desired; however, the loss of alloying elements creates a problem in composition control. Figure 3 is a plot of vapor pressures of elements of interest in steelmaking as a function of temperature. The alloy element of greatest concern in vacuum melting of high strength steels is manganese, which has a high vapor pressure; therefore, it can be added to the molten bath a) under an increased pressure of inert gas or b) during the late stages of the refining cycle, and compensation is made for the loss.

EXPERIMENTAL PROCEDURE

Equipment

Figure 4 is a photograph of the 500 lb (steel) capacity vacuum induction melting furnace used in these investigations. The unit consists of a horizontal vacuum chamber with five sight glasses and wipers; alloy additions chamber; remote control unit for hydraulic tilting of furnace and vibratory feeder assembly; induction furnace; rotary mold table; standard valve assembly with immersion thermocouple, bridge-breaker and sampler and an inlet for introduction of an inert gas.

The pumping system, consisting of mechanical roughing and holding pumps, three boosters and an oil diffusion pump, permits reduction from atmospheric pressure to less than ten microns (approximately 10^{-5} atm pressure) in about 17 min with full charge and molds in the vacuum tank. Generally a pressure of less than ten microns can be maintained in the vacuum chamber throughout the entire cycle of a 250 lb steel heat. The power source is a motor generator set producing 175 kw at 440 volts and 960 cycles.

Mold Materials

Three types of mold materials were used in these investigations—zircon sand, ceramic alumina and cast iron ingot molds.

Table 3 lists the formula for a 100 lb batch of zircon sand. Zircon flour is first mixed with the sand. A solution of water, aluminum hydroxide (powder)

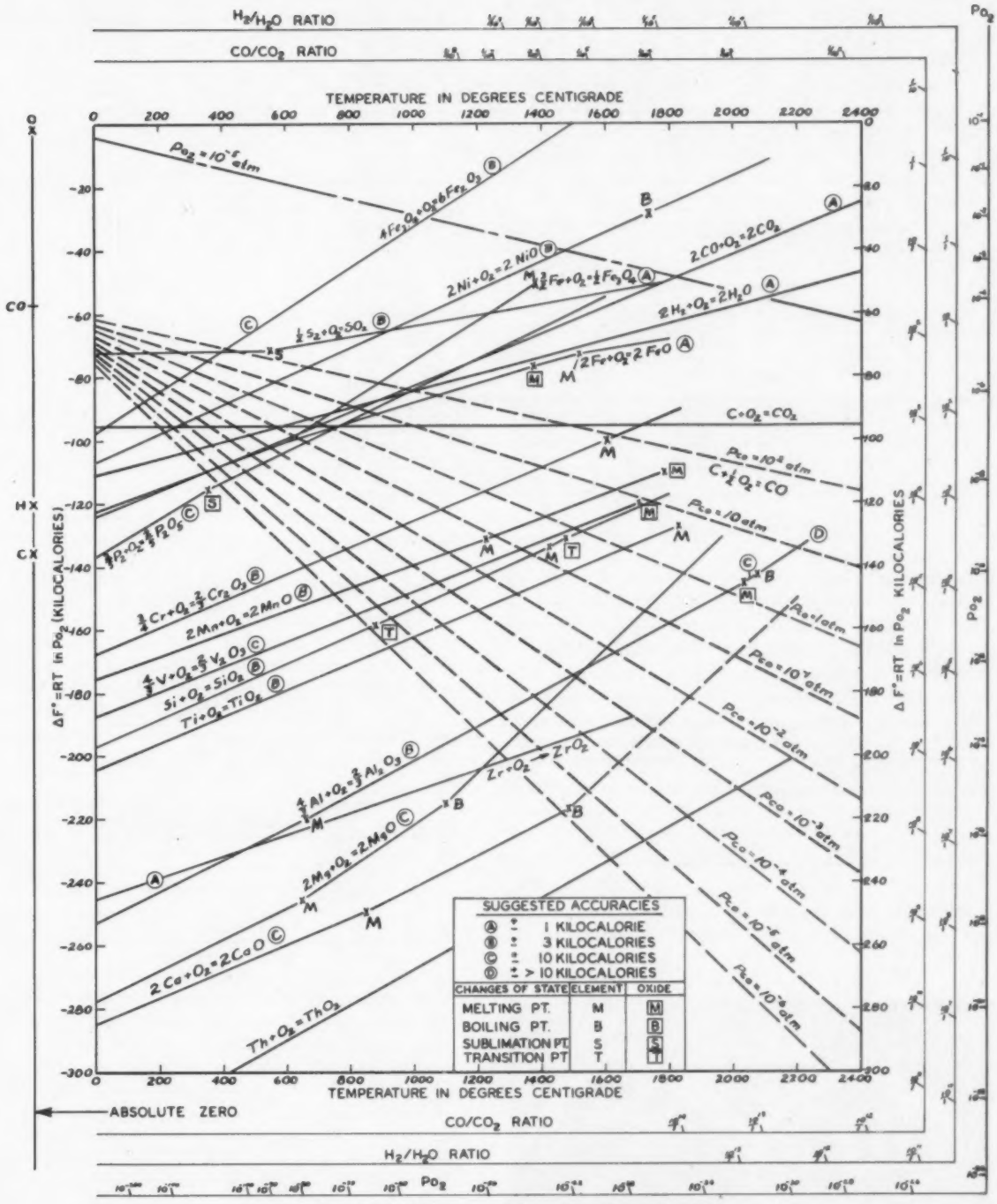


Fig. 2 — Standard free energy of formation of metal oxides of interest in steelmaking as a function of temperature.

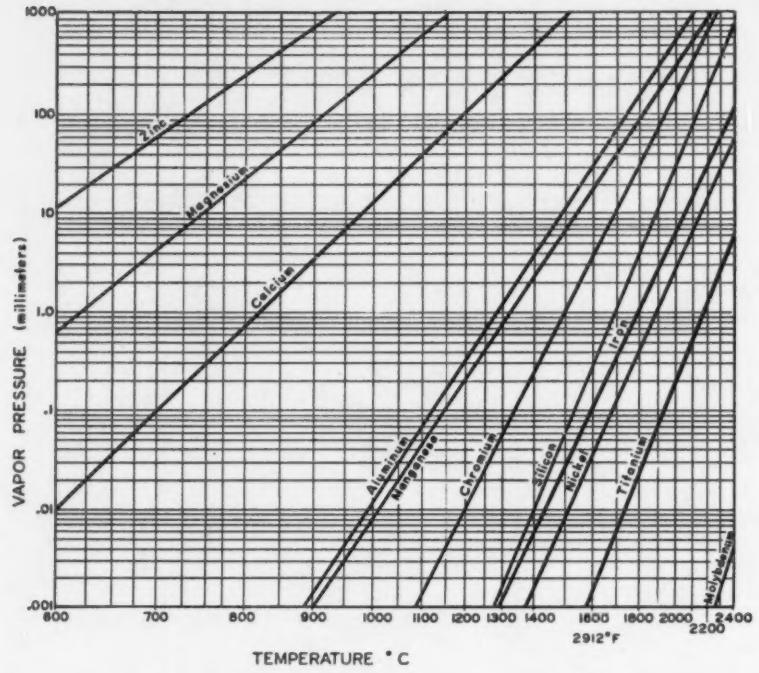


Fig. 3 — Vapor pressure of metals of interest in steelmaking as a function of temperature.

and phosphoric acid is made which is then added to the flour-sand mixture and thoroughly mulled. After ramming, the sand mold is placed in an oven for 8 hr at 450 F, then in a furnace at 2000 F for 4 hr and furnace cooled.

TABLE 3 — COMPOSITION OF 100 LB BATCH OF ZIRCON SAND

80 lb Zircon sand ($ZrO_2 \cdot SiO_2$)
20 lb zircon flour
1500 cc water
500 cc phosphoric acid (H_3PO_4)
712 grams aluminum hydroxide ($Al_2O_3 \cdot 3H_2O$)

In Table 4 is the list of ingredients for making a 15 lb batch of alumina slip.[7] Preparation of the slip is as follows. Water is placed into a crock and one-half of the alumina with the gum arabic dispersed through it is added to the water and stirred with a spatula. Two ounces of 3 normal hydrochloric acid is added, then the mixture is drill-whipped for several minutes with a high-speed disc. Next, the ball clay is added and the mix is again stirred, after which the remaining alumnia is added in two equal additions, with drill-whipping in between.

TABLE 4 — COMPOSITION OF 15 LB BATCH OF ALUMINA SLIP

175.5 oz alumina
45.0 oz water
12.0 oz pot ash feldspar
7.5 oz ball clay
1.5 oz gum arabic

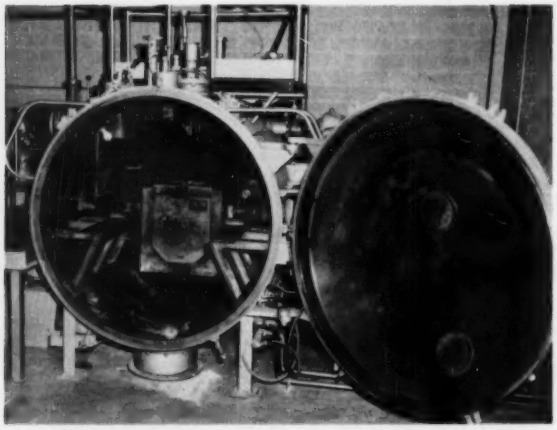


Fig. 4 — 500 lb (steel) vacuum induction melting unit.

Production of the mold begins by mounting the wax patterns as in the conventional lost wax process. The assembly of patterns, sprues and gates is immersed into the slip, then submerged into a fluidized bed of 90-mesh alumina abrasive grit. After drying for about 20 min, subsequent layers are built up to the desired thickness repeating the above process. After slow drying of the mold, wax meltout is accomplished in 3 min at 1625 F, and firing is done in 1½-hr at 1825 F. This is necessary to develop requisite strength levels in a mold of this composition.

The third mold material used were cast iron ingot molds. They are first shot blasted and then sprayed with either magnesia (MgO) or zirconia (ZrO_2) wash at approximately 300 F.

Melting

In the production of ultra high strength S.A.E. 4330 and 4340 steel castings utilizing vacuum induc-

tion technology, two methods of charging metal are used. One is to use bar stock (about 99.50 per cent Fe) and ferro-alloy additions; the other is to make a master alloy in air (or vacuum) which is then remelted in vacuum. In Table 5 is the chemical analysis

TABLE 5 — CHEMICAL ANALYSIS OF RAW MATERIALS USED IN PRODUCTION OF CONVENTIONAL VACUUM INDUCTION MELTED S.A.E. 4330 AND 4340 HIGH STRENGTH STEELS

	Analysis, %								
	C	Mn	Si	Cr	Ni	Mo	S	P	Fe
Bar Stock	0.14	0.27	0.15	0.01	0.02	0.01	0.016	0.010	bal
Pig Iron	4.55	0.91	1.51	0.01	0.03	0.01	0.019	0.010	bal
Ferromanganese	1.45	81.20	1.34	—	—	—	0.020	0.021	bal
Ferrosilicon	—	—	50.00	—	—	—	0.040	0.050	bal
Ferrochromium	0.07	—	0.39	69.03	—	—	0.045	0.055	bal
Ferromolybdenum	2.46	0.03	1.16	—	—	66.21	0.142	0.076	bal
Nickel	—	—	—	—	99.99	—	—	—	—

of raw materials used in the production of conventional vacuum induction melted high strength steels. Table 6 shows a typical analysis of charge materials used in the production of low sulfur vacuum melted high strength steels.

TABLE 6 — TYPICAL CHEMICAL ANALYSIS OF CHARGE MATERIALS USED IN PRODUCTION OF LOW SULFUR VACUUM INDUCTION MELTED S.A.E. 4340 STEEL

	Analysis, %								
	C	Mn	Si	Cr	Ni	Mo	S	P	Fe
Master Alloy	0.43	0.75	0.27	0.80	1.82	0.26	0.004	0.010	bal
Pig Iron	4.01	0.45	0.88	—	—	—	0.008	0.010	bal
Electrolytic Mn		99.9							

Bar stock or the master alloy billet is first shot blasted, then sometimes preheated. Effect of the preheat on the charge and alloy additions is to decrease moisture and surface gases. It is better to place the charge in the induction furnace, then increase the power input at a slow rate which in effect serves as a preheat and reduces absorbed gases.

Base charge materials and pig iron are placed in the crucible. Alloy elements are set in their prescribed locations in the additions chamber. The unit is sealed and then evacuated to a pressure of less than ten microns. Meltdown is completed after approximately one hr of heating including initial preheating time.

Refining

During meltdown and the refining period the carbon boil occurs, at which time most of the harmful gases, oxygen, hydrogen and nitrogen are removed. After a given time the boil essentially ceases, creating the condition of "metastable equilibrium." That is, equilibrium is only approached but not reached as reduction of the refractory crucible yields another source of oxygen.

Additions are made after the boil has ceased in the melt. Power is then decreased slightly in an attempt to maintain a temperature and pressure at which the melt-crucible reaction is not favorable. This period is when most of the remainder of the hydrogen and nitrogen is removed by desorption due to inductive stirring, which continually exposes new molten surfaces to vacuum and facilities mass transfer of these elements from solution to their gaseous states.

Due to its high vapor pressure at steelmaking temperatures, manganese is added to the bath during this late stage of the refining period, and compensation is made for its predetermined loss.

A molten sample is obtained if desired and the temperature is measured using an immersion thermocouple. Both of these steps are accomplished through the hold valve assembly without releasing vacuum. Figure 5 illustrates a typical melting, refining and casting cycle.

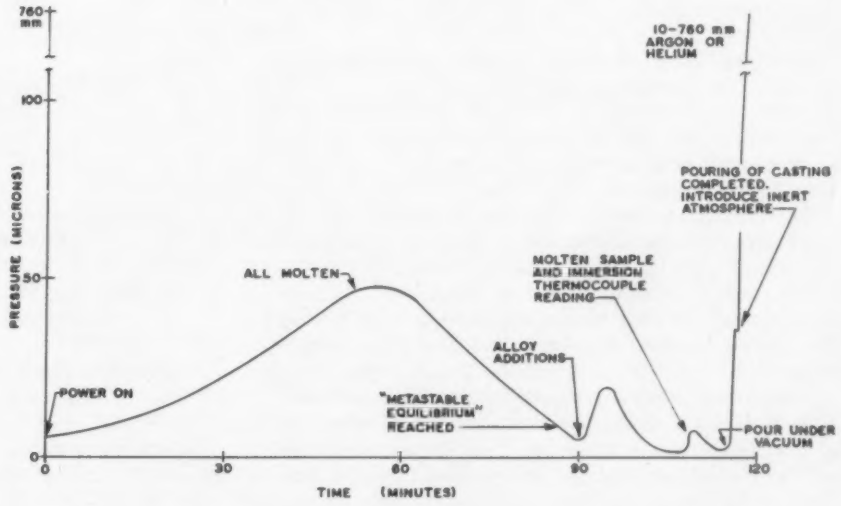


Fig. 5 — Optimum melting, refining and casting cycle of vacuum induction melted high-strength steel.

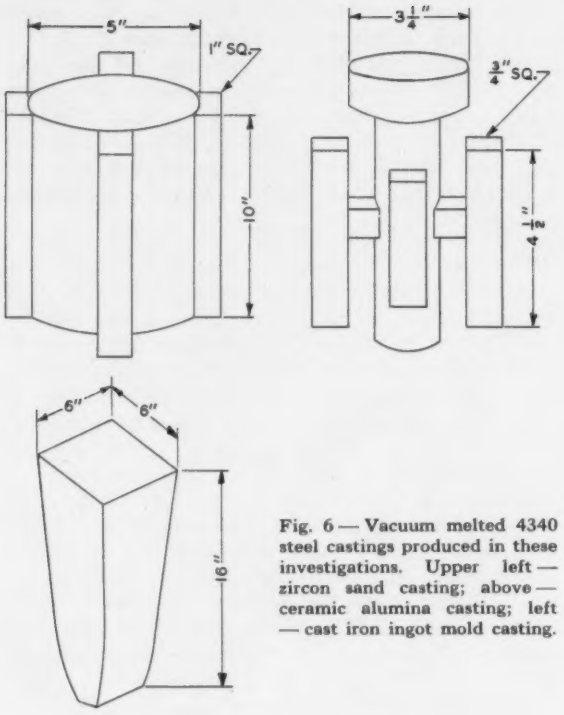


Fig. 6 — Vacuum melted 4340 steel castings produced in these investigations. Upper left — zircon sand casting; above — ceramic alumina casting; left — cast iron ingot mold casting.

Casting

After the desired refining time, pressure and temperature are attained, the heats are then poured into either a zircon sand mold, cast iron ingot mold or ceramic alumina mold (Fig. 6). There are three possible combinations of casting and solidification atmospheres available: a) pour and solidify under vacuum, b) pour under vacuum and solidify under inert atmosphere or c) pour and solidify under inert atmosphere.

If poured under dynamic vacuum conditions, that is, with the pumping system operating, a stream degassing effect is realized, resulting in lower residual gas content. The equilibrium partial pressures of the gases above the molten metal are greater than their actual partial pressures above the mold cavity, possibly leading to porosity due to gaseous evolution, especially if solidification also is accomplished under vacuum.

In a stagnant system, that is, with the chamber isolated and an inert atmosphere of argon or helium introduced, stream degassing will not be affected. Gases initially evolved from the metal during and after pouring tend to remain above the metal, and the equilibrium partial pressures of these gases increase to an extent where they are greater than the actual partial pressures in the casting, thereby preventing further evolution and favor sound castings. However, there is the possibility of introducing moisture and impurities from the inert gas.

It is concluded that the optimum casting and solidification conditions are to pour under dynamic vacuum conditions to gain the effect of stream degassing to obtain lower residual gas content. Immediately upon filling the mold, an inert gas is introduced for the following reasons. First, according to Sievert's Law, where the solubility of diatomic gases in molten metal, at a given temperature, is proportional to the square root of the partial pressure of gas in equilibrium with the metal, so that if the partial pressure of the gas is allowed to increase over the poured molten casting, a greater concentration of dissolved gases can exist in solid solution and prevent evolution during solidification.

Second, if the steel is cast into a refractory sand mold, increasing the pressure above the metal would tend to suppress any reaction involving dissolved carbon and mold material where carbon monoxide is a product. Third, the increased hydrostatic pressure head may aid in filling a mold where overcoming surface tension is necessary or in a nonpermeable mold to obtain finer detail.

Heat Treatment

Three methods of heat treating were employed in these investigations—either heat treating the casting as an entity, machining oversize blanks from the periphery of the ingots, or removing the fins from those castings which had them and then heat treat. Table 7 illustrates the optimum heat treating cycle developed for S.A.E. 4340 steel.

TABLE 7 — OPTIMUM HEAT TREATING CYCLE FOR S.A.E. 4340 ULTRA HIGH STRENGTH STEEL

Operation	Temp., F	Hold Time, hr
Homogenize	2200	8 air cool to room temp.
Normalize	1750	8 air cool to room temp.
Anneal	1225	12 Furnace cool to room temp.
Shot blast to remove scale		
Austenitize	1600	5
Drop to	1400	
Oil Quench	Room	2
Temper	{400 (low silicon) {500 (high silicon)	7
Quench	Room	
Temper	{400 (low silicon) {500 (high silicon)	7

Initially, the specimens are homogenized at 2200 F for 8 hr, then cooled in air down to room temperature. This treatment increases the uniformity of the steel by breaking up the dendritic structure. The next step is normalization at 1750 F for 8 hr, which dissolves all carbides, then air cool to room temperature. The function of the annealing treatment is to facilitate machining and removal of gates and risers if necessary.

Specimens are austenitized at 1600 F, then dropped to 1400 F and oil quenched. Lowering the temperature 200 F decreases the tendency to quench crack;

however, it allows the pieces to remain in the austenitizing range.

The optimum properties are obtained by tempering at 400 F for low silicon specimens and 500 F for high silicon. Double tempering is utilized to avoid untempered martensite from forming by retained austenite decomposition.

RESULTS AND DISCUSSION

Residual Gas Content

Major improvements in mechanical properties of ultra high strength steels, especially ductility and toughness at high strength levels, are obtained substantially from the reduction of residual gas contents of oxygen, hydrogen and nitrogen. This is accomplished by the carbon boil and inductive stirring mechanism, as described in the section on degassification.

Table 8 shows the gas contents of the input materials as determined by vacuum fusion analysis in the production of conventional vacuum induction melted S.A.E. 4340 steel using bar stock and ferroalloys.

TABLE 8 — GAS CONTENTS OF CHARGE MATERIALS USED IN CONVENTIONAL VACUUM INDUCTION MELTED S.A.E. 4340 STEEL

	Weight per cent		
	Oxygen	Hydrogen	Nitrogen
Bar Stock	0.0206	0.00014	0.0012
Pig Iron	0.0830	0.0005	0.0020
Nickel	0.0115	0.0003	N.D.
Ferrochromium	0.0340	0.0004	0.0420
Ferromolybdenum	0.0140	0.0006	0.0040
Ferromanganese	0.0015	0.0007	0.0810
Aluminum	0.0016	0.0005	0.0011

Substantial reduction in gas content is obtained after melting, refining and casting under vacuum or controlled atmosphere. A comparison is made in Table 9 of the gas concentration present in the steel charge, vacuum induction, air induction and air arc furnace melted 4340 steel castings.

TABLE 9 — COMPARISON OF RESIDUAL GAS CONTENTS OF VACUUM AND AIR MELTED CASTINGS OF 4340 STEEL

	Weight Per Cent		
	Oxygen	Hydrogen	Nitrogen
Charge Material	0.0251	0.00018	0.0029
Vacuum Induction	0.0003	0.00001	0.0005
Air Induction	0.0030	0.00010	0.0053
Air Arc	0.0031	0.00017	0.0039

It is seen in Table 10 that the oxygen, hydrogen and nitrogen reduction in vacuum induction melted steel is 83.7:1, 18.0:1 and 5.8:1, respectively, whereas the decrease in air induction melted for oxygen is 8.4:1 and 1.8:1 for hydrogen. The reduction in air arc furnace melted 4340 steel is 8.1:1 for oxygen, while hydrogen remains substantially the same. Both air melting processes result in an increase of nitrogen.

TABLE 10 — REDUCTION OF RESIDUAL GAS CONTENT FROM CHARGE MATERIALS TO VACUUM AND AIR MELTED 4340 STEEL CASTINGS

	Oxygen	Hydrogen	Nitrogen
Vacuum Induction	83.7:1	18.0:1	5.8:1
Air Induction	8.4:1	1.8:1	Increase
Air Arc	8.1:1	1.1:1	Increase

The actual average residual oxygen content of vacuum melted 4340 steel is 0.0003 weight per cent as shown in Table 9. However, this concentration deviates from the equilibrium oxygen content of 5.76×10^{-8} per cent calculated in equation (14b). It is suggested that this deviation is caused by the magnesia crucible being reduced by dissolved carbon forming magnesium (gas), and oxygen which enters into solution and reacts with carbon to form carbon monoxide gas. That is, the melt-crucible, deoxidation and distillation reactions occur simultaneously, as follows:

$$MgO\,(\text{crucible}) = Mg\,(\text{soln.}) = \underline{O}\,(\text{soln.}); \quad \text{crucible reduction} \qquad (20)$$

$$\underline{C}\,(\text{soln.}) + \underline{O}\,(\text{soln.}) = CO\,(\text{gas}); \quad \text{deoxidation} \qquad (10)$$

$$Mg\,(\text{soln.}) = Mg\,(\text{gas}); \quad \text{distillation} \qquad (21)$$

Figure 7 shows the gain of oxygen from the melt-crucible reaction and the loss of oxygen due to the carbon deoxidation reaction, both as a function of refining time. At a given pressure and temperature, the above reactions will occur. The oxygen loss is determined by a weight balance with the carbon loss and the gain of oxygen from the MgO can be determined for the following relationship:

$$\text{Initial oxy.} - \text{Final oxy.} = \text{Grain of oxygen from MgO} - \text{Loss of Oxy. by CO reaction} \qquad (22)$$

The initial and final oxygen contents are measured by vacuum fusion gas analysis. It is assumed that all oxygen removal is in the form of carbon monoxide.

The difference in both curves at a given time determines the net loss or gain of oxygen in the melt. Therefore, the minimum point of this curve yields the optimum refining time which should be utilized in vacuum refining of these ultra high-strength steels. This minimum point occurs at approximately 45 min, i.e., 45 min should elapse from the time of completion of meltdown through the refining period to the final casting operation for optimum (lowest) residual oxygen content. After approximately 73 min of refining, oxygen reversion occurs; that is, the rate of oxygen gain in the melt is greater than the rate of loss. It is thus seen that excessive refining time is detrimental.

The above results are not in agreement with the original conception, where it was expected that the oxygen concentration would gradually decrease with

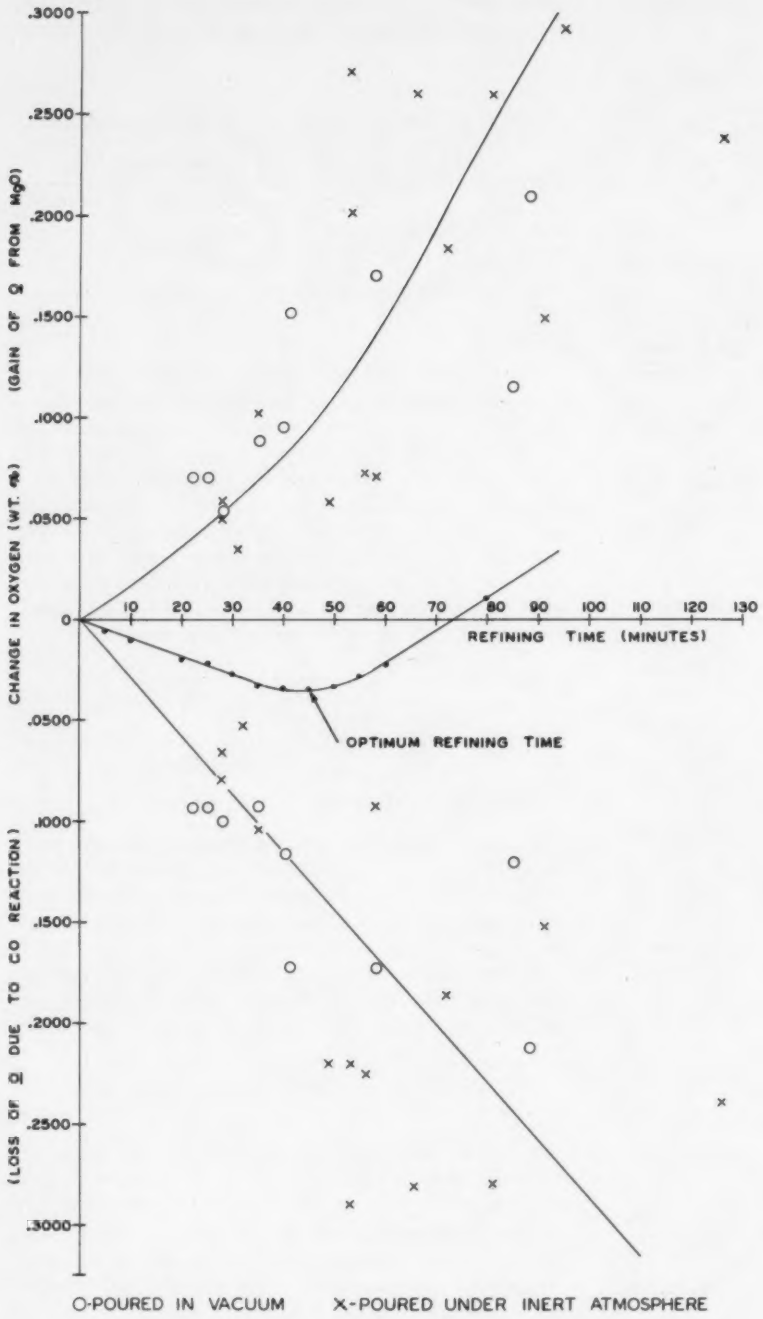


Fig. 7 — Plot of gain of oxygen from melt-crucible reaction and loss of oxygen due to deoxidation reaction as a function of refining time.

time and approach zero concentration at long refining times. However, the results do show that at optimum refining times, extremely low oxygen concentrations (0.0003 weight per cent and lower) are obtained. It must be remembered that these results are for specific operating conditions, and certainly can be further improved by additional refinements in the procedures.

Nonmetallic Inclusions

The nonmetallic inclusions found in steel castings are classified as a) those inclusions owing their origin to the solubility of certain materials in steel and those resulting from chemical reactions occurring in the molten metal and b) those resulting from mechanical entrapment of refractories and mold materials.

Nonmetallic and mechanical inclusions can be especially detrimental in steel at the high strength levels, where they may exercise a severe stress concentration effect and lead to failure. As temperature decreases, the solubility product curve of silicon and oxygen, for example, is decreased, which results in precipitation of silica inclusions during solidification.

Vacuum refined steels containing sufficient carbon would have oxygen contents below the solubility product curve at the solidification temperature, resulting in the reduction in size and frequency of silica inclusions. Another possible reason for increased cleanliness is that some nonmetallics have high vapor pressures at steelmaking temperatures and the degree of vacuum attained during refining may volatilize these impurities.

Figure 8 shows the relative cleanliness of vacuum induction melted 4340 steel compared to an air induction melted 4340 steel containing Type 1 and 2 inclusions. The marked decrease in inclusion count demonstrates the cleanliness of the vacuum produced steel. Similar comparison of vacuum material and conventional air melted steel results in the same relative superiority of the vacuum product.

Segregation

It is seen in Table 11 that virtually no macrosegregation occurs in vacuum melted castings; however, this may be attributed to proper thermal gradients during solidification.

TABLE 11 — CHEMICAL ANALYSIS OF A VACUUM MELTED CAST IRON-INGOT MOLD CASTING, AT VARIOUS LOCATIONS

	Analysis, %								
	C	Ni	Cr	Mo	Mn	Si	S	P	Fe
(1)	0.425	1.85	0.73	0.25	0.63	0.34	0.014	0.015	bal
(2)	0.42	1.87	0.73	0.24	0.63	0.34	0.015	0.014	bal
(3)	0.425	1.90	0.73	0.24	0.63	0.34	0.022	0.015	bal
(4)	0.42	1.87	0.73	0.24	0.64	0.32	0.016	0.015	bal
(5)	0.42	1.87	0.73	0.25	0.64	0.34	0.023	0.015	bal
(6)	0.42	1.87	0.73	0.25	0.64	0.36	0.017	0.016	bal
(7)	0.42	1.86	0.73	0.25	0.63	0.34	0.016	0.016	bal
(8)	0.42	1.87	0.73	0.25	0.66	0.34	0.014	0.015	bal
(9)	0.42	1.82	0.73	0.25	0.63	0.34	0.015	0.016	bal
(10)	0.415	1.84	0.73	0.25	0.65	0.34	0.017	0.015	bal

Sections which solidify rapidly seldom show a clearly-defined dendritic structure upon etching; not

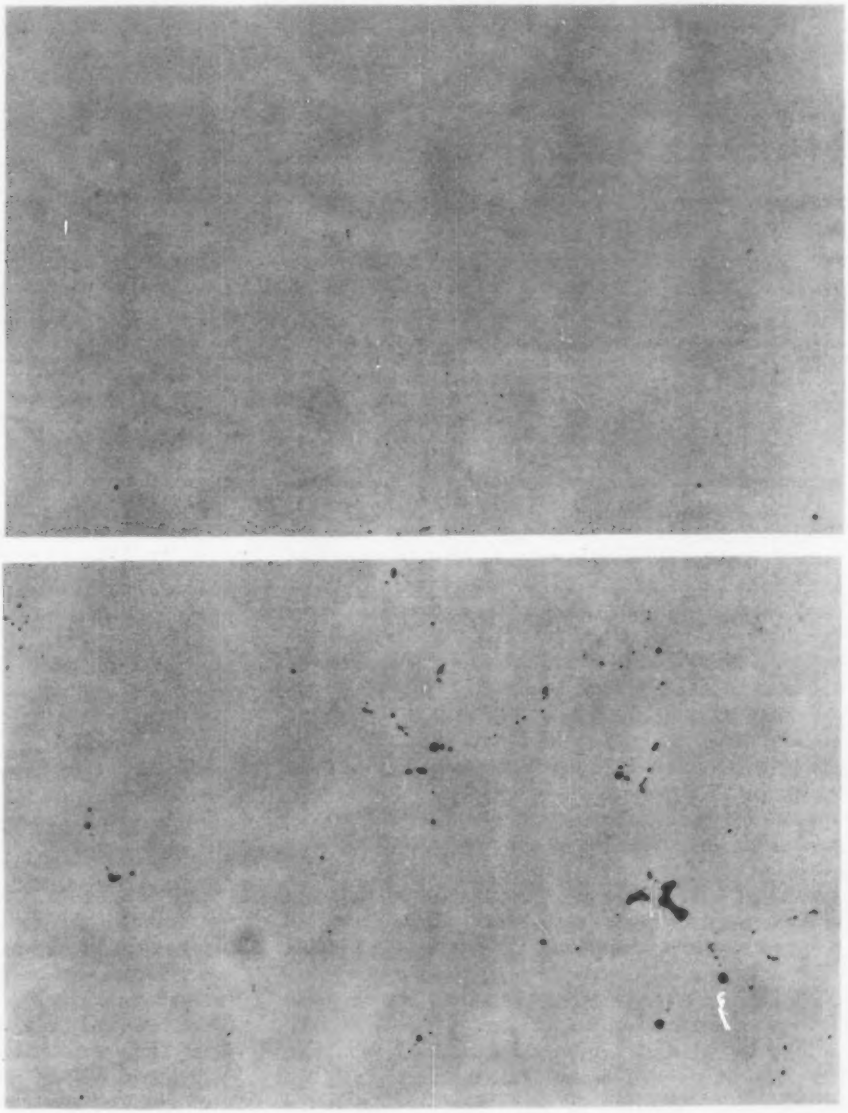


Fig. 8 — As-cast microstructure of vacuum induction melted and conventional air induction melted 4340 steel. Top — vacuum melted; bottom — air melted. Unetched. 100 ×.

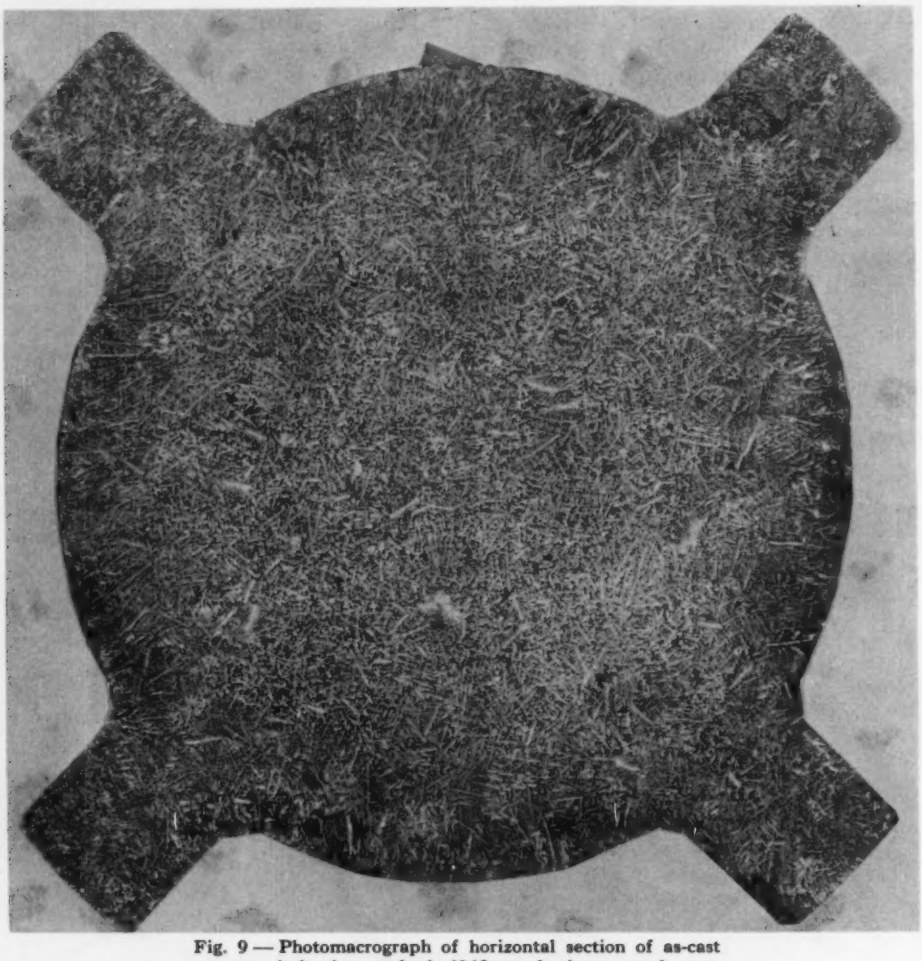


Fig. 9 — Photomacrograph of horizontal section of as-cast vacuum induction melted 4340 steel zircon sand casting containing 0.021 weight per cent sulfur. Actual size.

because there is none developed, but rather because there is insufficient time for dendritic segregation. To be effective, an etching treatment must be selective in its action, and in order to be selective the specimen must be chemically or physically heterogeneous. Steels with low impurity contents, such as sulfur and phosphorus, do not exhibit as pronounced a dendritic structure compared to steel with nominal amounts of these impurities.

Figure 9 is a photomacrograph of a horizontal section of an as-cast, vacuum produced 4340 steel containing 0.021 per cent sulfur and 0.014 per cent phosphorus. Figure 10 shows a steel processed in the same manner with the same composition; however, its sulfur and phosphorus contents are 0.003 and 0.013 weight per cents, respectively. Both of these specimens were etched in a solution of 12 per cent sulfuric acid, 38 per cent hydrochloric acid and 50 per cent water for approximately 20 min at 170 F. The macrographs clearly illustrate the almost complete absence of sulfide inclusions from the dendritic interstices in the low sulfur steel.

Presence of darkly-colored areas of silver sulfide show the relative amounts of sulfur present in the two specimens in the sulfur prints in Fig. 11. This figure shows that the low sulfur steel contains much less sulfur and sulfide inclusions, which should result in increased ductility and toughness.

Absolute gaseous segregation is lower in vacuum melted castings because a lower gas content is present when solidification begins; however, local segregation still occurs. Figure 12 illustrates the locations of specimens obtained for vacuum fusion gas analysis of oxygen, hydrogen and nitrogen (although nitrogen is not quantitative by this method) from an as-cast vertical section of an ingot. From Table 12 it is observed that a lower residual gas content is associated with the columnar zone in a casting and the concentration increases in the equiaxed zone toward the center.

Mechanical Properties

To evaluate the effect of lower residual gas content, reduction in size and distribution of nonmetallic and mechanical inclusions, low sulfur content, tempering temperature and mold materials, standard 0.357 in. tensile and 0.394 in. V-notch Charpy impact specimens were obtained from the fins or periphery of the castings. The tensile specimens were tested for yield strength at 0.1 and 0.2 per cent offset, ultimate tensile strength, per cent elongation and per cent reduction

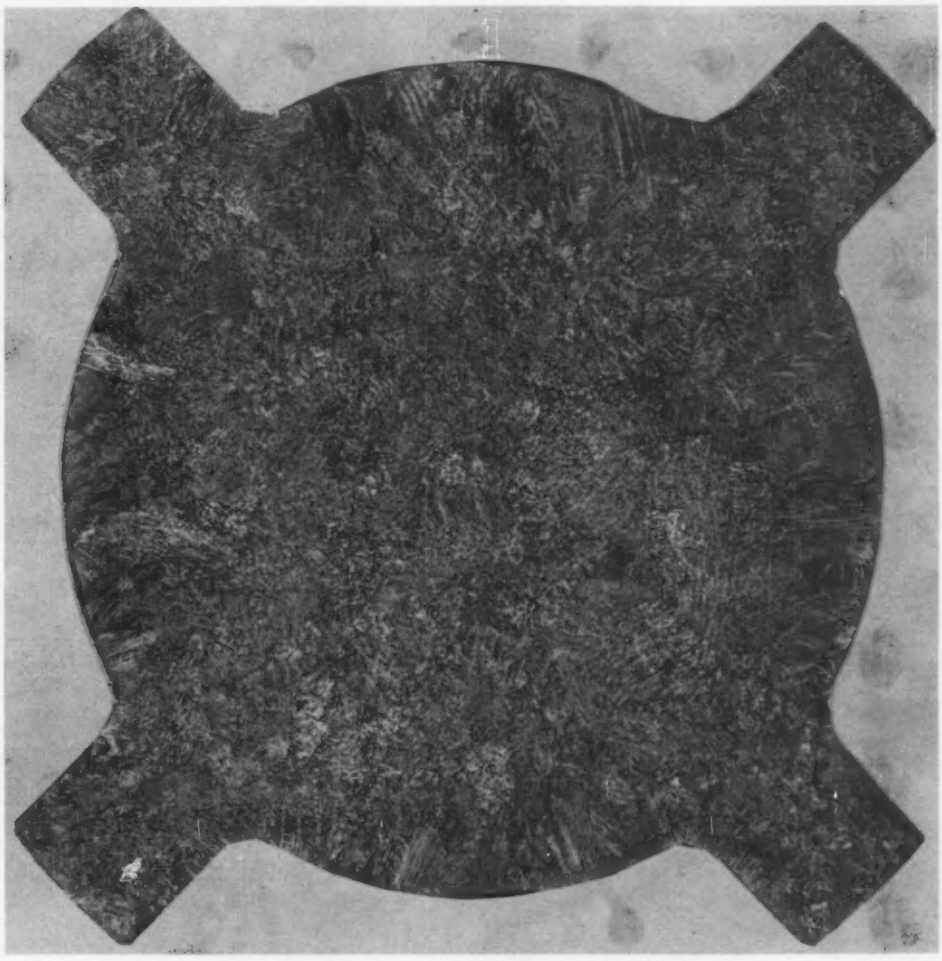


Fig. 10 — Photomacrograph of horizontal section of as-cast vacuum induction melted 4340 steel zircon sand casting containing 0.003 weight per cent sulfur. Actual size.

TABLE 12 — RESIDUAL GAS CONTENT OF SPECIMENS*

	Oxygen	Hydrogen	Nitrogen
(a)	0.00030	0.000004	0.00028
(b)	0.00007	0.000004	0.00018
(c)	0.00006	0.000006	0.00026
(d)	0.00002	0.000008	0.00042
(e)	0.00008	0.000018	0.00023
(f)	0.00014	0.000016	0.00004
(g)	0.00052	0.000045	0.00039
(h)	0.00010	0.000006	0.00008
(i)	0.00009	0.000004	0.00003
(j)	0.00009	0.000003	0.00004
(k)	<0.00001	<0.00001	0.00009
(l)	<0.00001	<0.00001	0.00009

*Obtained from locations as shown in Fig. 12 of an as-cast vertical section of an ingot of vacuum remelted 4340 steel (weight per cent).

of area. Impact energy necessary for fracture of Charpy specimens was measured at −40° (−40 C = 40 F). These results of vacuum melted S.A.E. 4340 steels are compared to air induction melted steels produced using the same thermal gradients during solidification, as seen in Table 13. Also listed in the same table with the physical properties are their corresponding chemical analysis and residual gas content.

It is seen that at a given tensile strength, ductility—as measured by per cent elongation and reduction in area, and toughness—as measured by impact energy for fracture, are substantially increased in vacuum produced high strength steels over those manufactured by conventional air induction methods. This is true especially at the highest strength levels where a silicon content in excess of one weight per cent is used.

The greatest improvement occurs at this level in the vacuum produced castings, because in air melted steel this high silicon concentration leads to formation of larger and more numerous nonmetallic inclusions. Also, reduction in sulfur from 0.019 to 0.004 weight per cent in vacuum melted steels increases the ductility still further. It is anticipated that with continued refinement of vacuum and controlled atmosphere melting, refining, casting and solidification techniques, consistent properties of S.A.E. 4340 steel castings can be obtained to yield the following results:

Y.S., @ 0.1%	Y.S., @ 0.2%	U.T.S.	Elong., %	R.A., %	Charpy Impact, @ −40°
230,000 psi	245,000 psi	295,000 psi	10.0	25.0	10.0 Ft-lb

TABLE 13 — MECHANICAL PROPERTIES OF 4330 AND 4340 VACUUM AND AIR INDUCTION MELTED STEEL CASTINGS PRODUCED IN THESE INVESTIGATIONS

	C	Ni	Cr	Mo	Mn	Si	S	P	Y.S., 0.1%, psi	Y.S., 0.2%, psi	U.T.S., psi	El., %	R.A., %	Charpy Impact, −40°, ft-lb
Air - IBZ	0.38	1.95	1.27	0.28	0.86	1.11	0.017	0.010	218,000	234,000	290,500	5.7	6.0	6.0
									219,500	235,000	290,000	7.1	9.8	7.1
	Hydrogen		Nitrogen		Oxygen		Temper @		217,500	233,000	288,800	5.0	9.3	8.3
	0.00008		0.00820		0.00430		400 F-OQ		217,000	232,500	290,000	5.7	11.4	8.7
Air - 2BZ	0.40	1.95	1.24	0.25	0.84	0.26	0.017	0.010	215,500	225,000	277,000	10.0	22.1	7.8
									212,500	225,500	273,500	8.6	13.0	8.4
	Hydrogen		Nitrogen		Oxygen		Temper @		215,000	228,000	275,000	7.1	14.0	9.0
	0.00008		0.00602		0.00532		400 F-OQ		213,000	227,000	275,300	7.1	16.1	10.2
Vacuum-HP-3MZ	0.41	1.78	0.87	0.24	1.13	1.10	0.005	0.011	202,500	218,000	298,000	7.9	20.1	13.6
									206,000	221,500	296,000	8.6	19.6	13.0
	Hydrogen		Nitrogen		Oxygen		Temper @							
	0.00002		0.00029		0.00012		400 F-WQ							
Vacuum-HP-4BZ	0.375	1.83	0.87	0.25	0.82	0.39	0.014	0.010	192,500	206,000	260,000	8.6	26.5	13.0
									192,500	207,000	260,000	10.0	28.9	13.0
	Hydrogen		Nitrogen		Oxygen		Temper @		193,000	207,000	262,500	8.6	28.4	13.0
	0.00003		0.0001		0.00018		400 F-WQ		192,000	205,000	261,800	10.0	29.4	13.5
Vacuum-VP-5MZ	0.42	1.69	0.88	0.24	0.98	1.18	0.004	0.012	233,500	244,000	290,000	9.3	23.1	10.1
									233,000	247,500	290,500	9.3	20.6	10.0
	Hydrogen		Nitrogen		Oxygen		Temper @		235,000	248,500	292,000	7.1	12.4	11.0
	0.00002		0.00013		0.00028		500 F-WQ		233,700	248,500	288,600	8.6	25.3	12.6
Vacuum-VP-6MZ	0.335	1.87	0.79	0.22	0.36	0.35	0.014	0.012	191,000	207,000	255,000	10.7	32.6	14.9
									194,000	209,000	256,000	10.7	33.5	14.9
	Hydrogen		Nitrogen		Oxygen		Temper @		199,000	212,500	258,000	9.3	28.9	12.7
	0.000004		0.0004		0.0001		300 F-WQ							
Vacuum-HP-7BZ	0.42	1.80	0.85	0.28	1.05	0.25	0.019	0.011	201,500	215,500	272,000	10.7	20.6	11.2
									200,000	215,000	271,000	8.6	20.6	11.3
	Hydrogen		Nitrogen		Oxygen		Temper @		198,000	213,500	271,000	8.6	22.6	11.6
	0.00001		0.00108		0.00043		400 F-WQ		202,000	216,500	272,000	10.0	21.6	11.7
Vacuum-HP-8BC	0.41	2.00	0.89	0.11	0.40	0.40	0.015	0.009	208,500	225,500	295,500	10.0	25.1	8.0
									207,500	225,500	294,000	10.0	24.6	10.0
	Hydrogen		Nitrogen		Oxygen		Temper @		192,000	213,000	267,000	9.3	24.1	8.1
	0.00003		0.00048		0.00124		300 F-WQ		207,500	229,000	298,000	7.1	12.4	7.8
Vacuum-VP-9MC	0.47	1.77	0.90	0.35	0.96	1.63	0.004	0.012	240,500	257,000	303,000	7.1	21.6	6.3
									242,500	258,000	307,000	6.4	18.1	7.0
	Hydrogen		Nitrogen		Oxygen		Temper @		242,500	258,000	308,000	6.4	18.6	7.7
	0.000007		0.00064		0.00004		550 F-OQ							
Vacuum-HP-10BZ	0.28	1.90	0.95	0.23	0.74	0.27	0.017	0.013	168,500	181,500	227,000	11.4	34.9	12.3
									172,000	183,500	228,500	10.7	27.5	12.8
	Hydrogen		Nitrogen		Oxygen		Temper @		170,000	182,000	225,500	10.7	34.9	12.0
	0.00002		0.0007		0.0007		400 F-WQ		107,000	179,500	226,500	10.0	32.2	12.2
Vacuum-VP-11MC	0.43	1.69	0.79	0.24	0.81	0.33	0.005	0.010	225,500	236,500	282,000	8.6	22.6	8.7
									225,000	237,000	281,300	7.1	23.1	9.1
	Hydrogen		Nitrogen		Oxygen		Temper @		222,000	232,000	282,500	7.1	17.6	9.9
	0.00001		0.00074		0.00036		400 F-OQ		227,000	237,000	284,500	6.4	7.6	12.0

Key:
Z — Zircon sand mold
C — Cast iron ingot mold
B — Bar stock
VP — Vacuum poured
HP — Helium poured
M — Master alloy

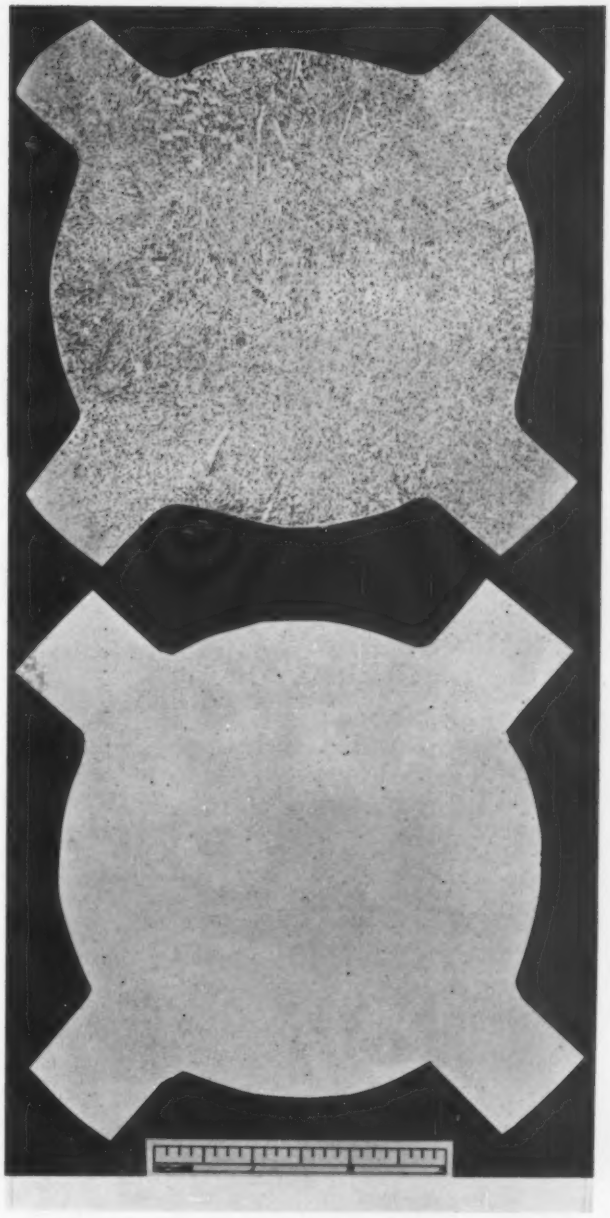


Fig. 11 — Sulfur prints of vacuum induction melted 4340 steel zircon sand castings containing 0.03 and 0.21 weight per cent sulfur. Left — 0.021 sulfur. Right — 0.003 sulfur.

CONCLUSIONS

Extremely low residual gas contents of ultra high strength steels are obtained by vacuum induction processing. Hydrogen and nitrogen are reduced to low levels by the inductive stirring mechanism which exposes new molten metal surfaces to vacuum, which facilitates mass transfer of these elements in solution to their gaseous states by desorption. Oxygen concentration is greatly reduced by the carbon boil, at which time atomic hydrogen and nitrogen diffuse into the carbon monoxide bubbles causing further reduction of these gases.

Residual gas contents of oxygen, hydrogen and nitrogen of 0.0003, 0.00001 and 0.0005 weight per cent, respectively, and lower, are attained in vacuum refined castings. This is a reduction in these gases of 83.7:1, 18.0:1 and 5.8:1 from the charge materials.

Carbon is the most effective deoxidizer of steel in vacuum for its deoxidizing power is increased as the partial pressure of carbon monoxide is reduced.

The actual oxygen content is higher than the predicted equilibrium oxygen concentration. This is caused by reduction of the crucible by dissolved carbon which provides an additional source of oxygen.

Lower residual gas content is associated with the columnar zone in vacuum produced steel castings whereas the concentration increases in the equiaxed zone toward the center.

Reduction in pressure enhances any reaction which yields a gaseous product from solid or liquid reactants as the dynamic vacuum conditions prevent equilibrium from being attained. As the gaseous products are continually removed from the system, the reaction is favored to proceed as written.

Removal of oxygen by dissociation of metal oxides in molten steel is not favored at the pressures attainable in the vacuum system. Possible exceptions are nickel oxide (NiO) and hematite (Fe_2O_3).

A large reduction in size and frequency of nonmetallic inclusions is achieved in vacuum induction melting over conventional air melting procedures. For example, precipitation of silica inclusions is not favored at the solidification temperature of vacuum melted steels containing sufficient carbon, as the oxygen content is below the solubility product curve of silicon and oxygen.

Magnesia is the optimum crucible material of the common refractory oxides for use in vacuum induction melting of steels for the melt-crucible reaction is the least favorable. The crucible should be designed with greater vacuum-melt interface area to increase gaseous removal and less crucible-melt area of contact to minimize crucible reduction.

Results of sulfur analyses confirm the theoretical calculations that desulfurization is not obtained in conventional vacuum induction melting by the elements already present in the steel, such as carbon, silicon, hydrogen, oxygen and sulfur distillation.

Due to its high vapor pressure at steelmaking temperatures, manganese is added to the steel bath late in the refining period and compensation is made for its predetermined loss.

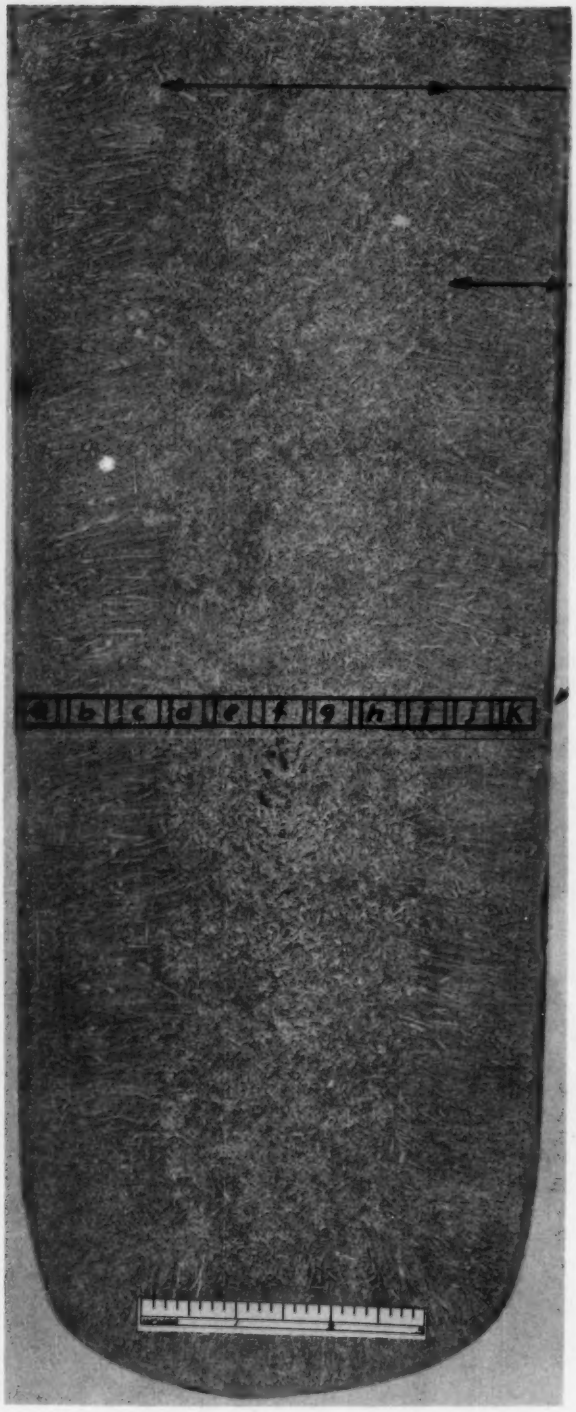


Fig. 12 — Locations of specimens obtained from vacuum fusion gas analysis of as-cast vacuum induction melted 4340 steel cast iron ingot mold casting. Top arrow — equiaxed zone. Second arrow — columnar zone. Lettered section — specimens for vacuum fusion analysis.

The optimum casting and solidification conditions are to pour under dynamic vacuum to gain the effect of stream degassing. Immediately upon filling the mold with molten steel, an inert atmosphere is introduced, the pressure of which is well above that associated with the equilibrium gas concentration in the metal at the time of pouring.

Mechanical properties of vacuum induction melted and air induction melted S.A.E. 4340 high-strength steels, both with the same thermal gradients during solidification, have been attained as follows:

	Y.S., 0.1%, psi	Y.S., 0.2%, psi	U.T.S., psi	Elong., %	R.A., %	Charpy Impact, −40°, ft-lb
(0.25-0.30 Si)						
Vacuum	207,000	225,000	295,000	9.9	24.5	9.0
Air	214,000	226,000	276,000	8.3	16.0	8.7
(1.1-1.2 Si)						
Vacuum	233,000	247,000	290,000	8.6	20.3	10.4
Air	218,000	234,000	290,000	5.9	9.1	7.5

It is seen herein that ductility and toughness, especially at the ultra high strength levels, are substantially improved in vacuum produced steels over those melted in air. This is caused by reduction in nonmetallic inclusions and lowering of residual gas content in vacuum. Reduction in sulfur causes further improvement in these properties. These data pertain to the best heats in air and vacuum and represent an average of at least four test specimens.

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HYPOEUTECTIC GRAY CAST IRON LADLE ADDITIONS

Graphite, silicon, aluminum & calcium additions effect on solidification, microstructure and mechanical properties

by D. D. McGrady, C. L. Langenberg, D. J. Harvey and H. L. Womochel

ABSTRACT

This progress report gives additional data on the effectiveness of pure silicon and aluminum as addition agents, and presents data on graphite as an inoculant. Data are presented on the effect of calcium, silicon aluminum and graphite additions on the eutectic temperature. Experiments designed to determine the effect of these elements on the nucleation of solidification and transformation of hypoeutectic irons are described.

INTRODUCTION

Data obtained from a study of the relative effectiveness of some late addition agents on the mechanical properties and microstructure of hypoeutectic cast irons were presented in a previous report.[1] Included in this study were various grades of ferrosilicon, calcium-silicon and a complex silicon alloy containing zirconium. The effects of the late addition of calcium, aluminum and silicon in the pure form were also determined. The following conclusions were listed in this paper.

1) The most effective inoculating alloy was calcium silicon containing approximately 30 per cent of silicon. The superiority of the high calcium alloy over ferrosilicon was marked.
2) The various grades of ferrosilicon increased in their inoculating power with increasing content of calcium and aluminum. A grade of ferrosilicon low in active metal content was without value as an inoculant.
3) An alloy of silicon and manganese which contained only traces of calcium was not effective as an inoculant.
4) Additions of the element silicon (purified silicon, 99.8 per cent silicon, balance iron) were without effect.
5) Metallic calcium additions ranging from 0.10 to 1.00 per cent were effective in improving properties and microstructure.
6) Metallic calcium additions effected a reduction of eutectic cell size, indicating a nucleation of eutectic solidification.
7) Metallic calcium additions effected a decarburization of melts indicating the formation of an insoluble carbide of calcium.
8) Addition of 0.07 and 0.5 per cent aluminum were not effective in improving graphite distribution, but were effective in reducing chilling tendency.

These results were strongly indicative of the major role of calcium in inoculation, and tend to discredit theories based on the addition of silicon. The possibility of a theory based on the agency of calcium was indicated.

EXPERIMENTAL PROCEDURE

Some of the heats of this report were melted in a 250 lb indirect-arc furnace. The others were melted in a 30 lb high frequency induction furnace. Charges for the indirect-arc, rocking furnace consisted of pig iron, steel scrap and 27 per cent ferrosilicon as a cold charge. Manganese and sulfur contents were adjusted immediately after the meltdown with ferromanganese and iron sulfide. All melts were brought to 2850-2900 F as determined by the optical pyrometer, and were tapped in this range. Pouring temperatures were determined either with the optical instrument or a platinum-platinum rhodium couple, and were in the range of 2650-2750 F.

All ladle additions of alloys, graphite and of pure silicon were made by tapping a small amount of metal and then adding the inoculant continuously as the balance of the iron entered the ladle. In the case of treatments with active metals, the metal was wired to an iron rod and plunged beneath the surface of the molten iron. The time interval between tapping and pouring was 2 to 4 min.

Metal from each ladle was poured into dry sand core, 1.2 in. standard test bar molds washed with a noncarbonaceous wash. These bars were broken on 18 in. centers in accordance with standard procedure. All transverse test bar results are the average of three or more bars. Small wedge chill test specimens were

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used in some experiments; in others a chill block specimen was employed.

Tensile test results were not reported in most cases. As the work continued it became evident that the transverse breaking load, the deflection and in particular the triangular resilience provided a more sensitive index of variation in microstructure and the effectiveness of inoculants than did the tensile strength. Triangular resilience was computed by multiplying deflection by one half of the transverse breaking load.

Carbon and silicon contents of the irons were determined on each ladle. Sulfur, manganese and phosphorus contents were determined only on one ladle from each heat, unless these elements were involved in the additions or when there was reason to believe that their contents were altered in some way by the ladle addition.

The microstructure of all significant iron of this and the previous report were examined, and it was concluded that the results of the transverse test were closely correlated with variations in microstructure. The presence of a large proportion of type *A* graphite, particularly at the surface of the casting, seems to be effective in producing a high transverse breaking load and a high deflection. Typical photomicrographs were presented in the first report where it was shown that calcium and calcium-silicon alloy were particularly effective in producing type *A* graphite at and near the surface of the 1.2 in. section.

The induction melts were made in a 30 lb magnesia crucible. Charges consisted of arc furnace remelt, ingot iron punchings and 27 per cent ferrosilicon as a cold charge. Manganese, sulfur and phosphorus contents were adjusted immediately after the meltdown with additions of ferromanganese, ferrophosphorus and iron sulfide. Melts were brought to 2850-2900 F as indicated by an optical pyrometer. The molten iron was transferred to a pouring ladle, and the additions made during the transfer or in the ladle. Pouring temperatures were 2650-2675 F as indicated by the optical pyrometer, or in some cases the immersion thermocouple.

EXPERIMENTAL RESULTS

In the experiments of this and the previous report, irons were produced in pairs to as nearly the same composition as possible with respect to carbon, silicon, manganese, phosphorus and sulfur, the only variable being the ladle addition. In some cases this involved taking two ladles from the same arc furnace heat; in other cases, where the addition produced a composition change with respect to one of the above elements, it was necessary to melt separate heats with the required adjustment of the cold charge to compensate for the changes in composition brought about by the addition.

In making comparisons between irons in these papers, an effort has been made to keep the carbon equivalents $\left(C + \frac{Si}{3}\right)$ within 0.1 of one per cent. This is a degree of control which compares favorably with that of similar experiments reported in the literature.

Silicon as an Inoculant

The principal theory for the inoculation of hypoeutectic gray cast iron has been based on a nucleation of solidification by silica or silicate particles formed by the addition of the silicon alloys which have been commonly employed as inoculants. These nuclei were credited with the prevention of undercooling, and formation of the undesirable types *D* and *E* graphite by the direct formation of type *A* graphite from the melt.

In the previous paper it was demonstrated that late additions of pure silicon and certain silicon alloys containing only traces of active metals were without value as inoculants, and produced no improvement of the graphite distribution or the mechanical properties.

Table 1 presents data on the effect of silicon and certain silicon alloys on the mechanical properties. In this and succeeding tables "Trans" refers to the transverse breaking load for the 1.2 in. standard bar, "Deflec" to the deflection in in., "Res" to the triangular resilience in in. lb and "Chill" to the chill depth in $\frac{1}{32}$-in. units. Under chill both clear chill, and clear chill plus mottled are reported. For example, the Figs. 8-21 would indicate a clear chill of $\frac{8}{32}$-in., and a total chill of $\frac{21}{32}$-in.

In these tables, the irons which afford a direct comparison are grouped together. Data from the previous paper are presented with new and confirming data on the effect of pure silicon in Table 1. The type of furnace used in melting is indicated in the table.

The first three irons of Table 1 were melted to determine the effect of pure silicon. T26-1 was treated with purified silicon (99.8 per cent Si balance Fe) for comparison with blank, untreated heats T25-2 and T27-1. Data on the mechanical properties of these irons indicate that an addition of silicon to a hypo-

TABLE 1 — DATA ON SILICON AS AN INOCULANT

Iron	Furnace	Addition	Trans., lb	Deflec., in.	Res. in./lb	Chill, $\frac{1}{32}$-in. Units	C, %	Si, %	Mn, %	P, %	S, %
T25-2	Arc	Blank	2575	0.230	296	12-18	2.84	2.24	0.80	0.122	0.062
T26-1	Arc	0.5% Si as pure Si	2533	0.210	266	13-36	2.87	2.32	0.85	0.115	0.066
T27-1	Arc	Blank	2490	0.232	289	12-20	2.84	2.39	0.83	0.122	0.066
T46	Induction	Blank	2610	0.205	267	23-46	2.84	2.08	0.91	0.164	0.068
T55	Induction	0.55% as pure Si	2460	0.201	247	20-48	2.83	2.05	0.90	0.131	0.058
T26-3	Arc	0.5% Si as Fe-Si alloy	2591	0.230	298	13-29	2.85	2.34	0.85	0.115	0.066
T27-1	Arc	Blank	2490	0.232	289	12-20	2.84	2.39	0.83	0.122	0.066
T3-1	Arc	0.18% Si as Si-Mn alloy	2364	0.184	217	32-52	2.88	2.31	1.06	0.075	0.062
T4-1	Arc	Blank	2580	0.218	284	16-35	2.94	2.34	1.00	0.077	0.062

TABLE 2 — DATA FOR PURE CALCIUM AND ALLOYS CONTAINING CALCIUM

Iron	Furnace	Addition	Trans., lb	Deflec., in.	Res. in./lb	Chill, 1/32-in. Units	C, %	Si, %	Mn, %	P, %	S, %
T39-1C	Arc	1.00% Calcium metal	3313	0.313	518	2-3	2.72	2.46	0.87	0.188	0.042
T32-2C	Arc	0.75% Calcium metal	3389	0.341	578	4-6	2.73	2.48	0.87	0.188	0.040
T40-1C	Arc	0.10% Calcium metal	3245	0.292	474	5-12	2.70	2.43	0.83	0.186	0.053
T40-1B	Arc	Blank	2390	0.191	228	12-28	2.74	2.47	0.83	0.186	0.054
T42-2B	Arc	Blank	2455	0.197	241	14-24	2.72	2.48	0.86	0.186	0.054
T2-C2	Arc	0.70% Si as Ca-Si Alloy	3728	0.394	745	4-8	2.84	2.21	0.99	0.102	0.046
T25-2	Arc	Blank	2575	0.230	296	12-18	2.84	2.24	0.80	0.122	0.062

eutectoid iron is without effect on the mechanical properties. Careful study of the microstructures revealed no effect of the silicon addition on graphite distribution or matrix structure.

Iron T46, a blank iron, and T55, treated with 0.55 per cent Si as pure silicon, were melted in the induction furnace as a check on the arc furnace heats. These results are in close agreement with the irons of the first group.

Iron-Silicon Alloy Treatment

Iron T26-3 was treated with an iron-silicon alloy designated as a low aluminum ferrosilicon (Si 93.00 per cent, Al 0.45 per cent, Ca 0.01 per cent, Fe balance). This alloy is not recommended as a commercial inoculant, and was employed in this research to provide additional data on the effect of silicon as an inoculant. Comparison of this iron with the corresponding blank T27-1 shows that late silicon in this form has a negligible effect on properties.

Heats T3-1 and T4-1 were melted to determine the effect of silicon additions made as a silico-manganese alloy. The alloy employed contained: Mn 65.50 per cent, Si 18.5 per cent, C 1.25 per cent, Ti 0.17 per cent, Fe balance (Ca and Al present only as traces). Comparison of these irons shows that the late addition of silicon as silico-manganese of this analysis is without benefit.

The results of Table 1 lead to the conclusion that the late addition of silicon to the low carbon, high strength irons is without beneficial effect. In some cases, it appears that the withholding of silicon for the purpose of a late addition is slightly detrimental rather than beneficial to properties.

It should be emphasized that these results were obtained with hypoeutectic, low carbon irons. The addition of silicon to high carbon iron has not been investigated in this research and may produce another result. The low carbon irons were selected for this investigation because of their strong tendency to produce type D and E graphite, and because of their sensitivity to the inoculating additions.

Calcium as an Inoculant

The lack of effectiveness of pure silicon, and of silicon alloys low in active metal content when compared with alloys containing appreciable amounts of calcium and aluminum, suggested the desirability of determining the effect of pure calcium and pure aluminum as inoculants. Data for pure calcium, and for a calcium-silicon alloy containing 31.72 per cent calcium, are presented in Table 2 with corresponding blank heats. In these experiments the metallic calcium addition was made by plunging the active metal on an iron rod.

These data are indicative of the major role played by the calcium in the various grades of ferrosilicon and calcium-silicon in the inoculation of cast iron. Calcium and calcium-silicon were the most effective inoculants employed in this research. Examination of the cross-sections of the transverse bars for the calcium treated irons showed the graphite distribution to be type *A* to the surface of the 1.2 in. bar, whereas bars of irons treated with silicon and ferrosilicon showed type *D* and *E* graphite at the surface and a tendency towards type *E* in the interior of the bar.

During the experiments with calcium and calcium-silicon, it was observed that calcium was effective in decarburizing the melts. For example, an addition of 1.00 per cent of calcium to an iron of approximately 3.00 per cent of carbon reduced the carbon content of the iron by 0.24 per cent C. This suggested the formation of insoluble calcium carbide. Examination of the ladles in which calcium, or large amounts of calcium-silicon additions were made showed them to be coated with a layer of powdered calcium carbide after cooling.

The formation of the carbide indicates the possibility of a theory for an inoculation mechanism based on nucleation of eutectic solidification by calcium carbide. As additional evidence for a nucleation theory, it was found that ladle treatment with calcium reduced the eutectic cell size. A tendency for calcium additions to effect a small reduction in the sulfur content was also observed. This reduction amounted to approximately 0.01 per cent in most cases.

Aluminum Additions Effect

Data for the effect of aluminum additions appear in Table 3. Data for the T34 irons are taken from the previous report. Data for the L25 irons are new, and were obtained for the purpose of determining the effect of small additions of aluminum. The amounts of aluminum employed are given in the table.

These results indicate that aluminum additions of the range investigated are ineffective in improving mechanical properties. In general, the aluminum produced little alteration in the microstructure either in the matrix or graphite distribution. In the case of one heat of arc furnace iron treated with 0.55 per cent aluminum, a greater tendency towards type *E* graphite was observed in the center of the aluminum treated bar as compared with the corresponding blank which tended more towards type *D*. However this was

TABLE 3 — ALUMINUM ADDITIONS

Iron	Furnace	Addition	Trans., lb	Deflec., in.	Res. in./lb	Chill, 1/32-in. Units	C, %	Si, %	Mn, %	P, %	S, %
L25-1	Arc	0.02% Aluminum	2357	0.196	231	16-32	2.84	2.29	0.74	0.141	0.061
L25-2	Arc	Blank	2340	0.200	234	16-32	2.84	2.29	0.74	0.141	0.061
L25-3	Arc	0.03% Aluminum	2175	0.175	191	18-33	2.84	2.31	0.74	0.141	0.062
L25-4	Arc	Blank	2332	0.200	233	18-33	2.82	2.33	0.74	0.141	0.061
T34-2A	Arc	0.07% Aluminum	2465	0.211	260	11-30	2.84	2.28	0.84	0.122	0.062
T34-2B	Arc	Blank	2455	0.212	258	14-23	2.82	2.31	0.84	0.122	0.061
T34-1A	Arc	0.50% Aluminum	2450	0.194	238	2-8	2.82	2.26	0.82	0.117	0.064
T34-1B	Arc	Blank	2478	0.212	260	8-31	2.84	2.33	0.86	0.122	0.064

TABLE 4 — GRAPHITE ADDITIONS

Iron	Furnace	Addition	C, %, Increase	Trans., lb	Deflec., in.	Res. in./lb	Chill, 1/32-in. Units	C, %	Si, %	Mn, %	P, %	S, %
L4T	Arc	0.47% Graphite	0.29	3140	0.325	507	4-8	2.83	2.20	0.84	0.175	0.062
L7B	Arc	Blank		2240	0.165	185	15-56	2.80	2.24	0.81	0.133	0.069
L5T	Arc	0.47% Graphite	0.22	2925	0.306	447	4-10	2.87	2.22	0.82	0.166	0.064
L8B	Arc	Blank		2375	0.198	235	16-44	2.92	2.19	0.80	0.164	0.062

exceptional. Large additions of aluminum produced a marked reduction in chilling tendency. It is apparent that a reduction of chilling tendency can be produced without the alteration of the graphite structure to type *A* from the abnormal structure of the untreated irons.

Graphite as an Addition Agent

Graphite has been extensively advertised and employed as an inoculant for gray iron. However, the data regarding the relative effectiveness of graphite are limited. Experiments to determine the effect of late addition of graphite on the mechanical properties and solidification were undertaken in this research in order to relate the effect of graphite additions to the other elements employed.

A commercial grade of graphite especially prepared for ladle additions was used. This graphite was 20 mesh and down. The graphite was added to the ladle during tapping. Not all of the graphite added dissolved prior to pouring, and the iron was poured from under the excess graphite.

Table 4 gives data for two graphite treated heats and the corresponding blank heats. The amount of graphite added in both cases was 0.47 per cent. The carbon pick up was 0.29 per cent in one case and 0.22 per cent in the other. All heats were induction melted as described under experimental procedure.

These data show that graphite additions are effective in improving mechanical properties and reducing chill. Examination of the microstructures of treated and untreated irons showed a marked improvement of graphite distribution resulting from the addition. In the untreated irons, the distribution was pronouncedly type *D* at both the surface and center of the cross-section of the 1.2 in. bar. In the treated irons, the distribution at center and surface was type *A* with a tendency towards type *E*, particularly at the surface. Cell size determination disclosed a reduction in cell size resulting from the graphite addition comparable to the reduction effected by additions of calcium and calcium silicon.

Additions on the Eutectic Temperature Influence

A considerable amount of attention has been devoted by several investigators to the influence of addition agents on the degree of undercooling and the temperature of eutectic solidification of cast iron. It has been generally agreed that inoculation involves a nucleation of eutectic solidification, and that inoculation is accompanied by an elevation of the eutectic temperature. The results of various investigations have substantiated this conclusion. The work of J. T. Eash[2] on the effect of inoculation with ferrosilicon on the eutectic temperature has received particular attention.

Eash poured inoculated and uninoculated irons ranging from 1.74 per cent to 2.37 per cent C into 3 in. section castings with a thermocouple located at the center of the section. Time-temperature curves, plotted for corresponding pairs of treated and untreated irons, showed an elevation of the eutectic temperature by the ladle treatment ranging from 36 to 70 F. Eash also performed quenching experiments on untreated irons in which he quenched castings of 1.2 in. section from 16 F below the eutectic temperature, and found the iron to be entirely white and free of graphite.

Since the untreated irons were gray with type *D* graphite when cooled normally to room temperature, it was concluded that untreated or abnormal iron solidified as white iron, and that type *D* graphite then formed from decomposition of cementite in the solid state. The idea that inoculation involved a nucleation accompanied by an elevation of the eutectic temperature has been generally accepted. However, the manner of origin of type *D* graphite has remained a controversial matter.

In view of the importance attached to the elevation of the eutectic temperature, experiments were undertaken in this research to determine the effect of the elements silicon, calcium, aluminum and carbon in the form of graphite on the temperature of eutectic freezing. Previous investigations have employed com-

plex alloys as additives, and it was hoped that the determination of the effect of the several elements would throw some additional light on the problem of the mechanism of inoculation.

Procedure

In these experiments two castings were employed. One was a 1.2 in. diameter bar 5 in. long. The other was a wedge shaped casting with a one in. by 2 in. rectangular cross-section tapering to ¼-in. by 2 in. at the reduced end. The length of this casting was 5 in. The wedge shaped casting was employed to facilitate some quenching experiments to be described later. All castings in these experiments were poured in open, dry sand core molds.

The thermocouples employed in these determinations were of 22 gage, chromel-alumel wire. The wire was protected by porcelain insulators and fused quartz tubes. The tip of the couple protruded from the protection tube and was coated with a thin wash of alundum cement. Time temperature curves were recorded automatically using a high speed, electronic recording device.

The thermocouple was positioned in the 1.2 in. diameter cylindrical mold at the midpoint of the length of the bar, and extending into the mold a distance of 3/16-in. The couple was positioned in this manner near the surface of the casting, because of the greater amount of undercooling to be expected at the surface and because the graphite exhibits a greater tendency towards the highly abnormal near the surface of the casting. This position differed from that of Eash where the couples were located in the center of the casting section. The couples for the wedge-shaped molds were also extended into the molds a distance of 3/16-in., and a distance of one in. from the heavy end of the casting. Pouring temperature in every case was 2650 F.

Results

Results for the eutectic temperature determinations are summarized in Table 5. Figures for two irons are reported in each case; one for the treated iron and the other for one of several blank irons. The blank iron selected for each pair was the one most nearly approaching the treated iron in composition. The corresponding irons are grouped in pairs in the table for comparison. The addition made to the treated iron is listed in the second column. In the case of graphite, the amount of the addition is the amount added to the ladle. The amount dissolved by the iron averaged about 50 per cent of the addition.

The third column lists the temperature for the start of eutectic solidification as determined from the strip chart of the recorder. The difference between the temperature for each treated iron and its corresponding blank is listed in the fourth column. This difference is the significant figure, and represents the amount of elevation of the eutectic temperature resulting from the addition. The remaining columns give the compositions of the irons and identify the casting as the cylinder or wedge previously described.

Figure 1 shows time-temperature curves for representative irons. These curves were obtained by transposing from the strip chart of the electronic recorder, and are presented in an effort to illustrate the general form of the curves. It will be noted that the curves for B-1 and B-2, which are blank or untreated irons, show an undercooling dip. The figures in the table showing the difference in eutectic temperatures are for the start of eutectic solidification, and there-

TABLE 5 — ADDITIONS EFFECT ON EUTECTIC TEMPERATURE

Iron No.	Addition, %	Temp. at start of Eutectic, F	Increase, F	C, %	Si, %	Mn, %	P, %	S, %	Casting
T55	0.55 Si as pure silicon	1980	10	2.83	2.05	0.90	0.131	0.058	Cylinder
T46	Blank	1970		2.84	2.08	0.91	0.164	0.068	Cylinder
L21	0.55 Si as pure silicon	2025	5	2.90	2.49	0.88	0.135	0.066	Wedge
L19	Blank	2020		2.92	2.46	0.91	0.117	0.067	Wedge
T48	1.00 Ca	2057	87	2.82	2.19	0.93	0.144	0.056	Cylinder
T45	Blank	1970		2.80	2.22	0.94	0.144	0.064	Cylinder
T49	1.00 Ca	2038	70	2.84	2.16	0.97	0.146	0.055	Cylinder
T47	Blank	1968		2.83	2.16	0.92	0.147	0.065	Cylinder
T53	1.00 Ca	2080	75	2.78	2.20	0.95	0.149	0.058	Wedge
T54	Blank	2005		2.78	2.26	0.90	0.149	0.067	Wedge
T51	0.60 Al	2040	70	2.84	2.10	0.87	0.154	0.068	Cylinder
T46	Blank	1970		2.84	2.08	0.91	0.164	0.068	Cylinder
T50	0.60 Al	2011	43	2.83	2.17	0.93	0.148	0.067	Cylinder
T47	Blank	1968		2.83	2.16	0.92	0.147	0.065	Cylinder
L4	0.50 Graphite	2020	52	2.83	2.20	0.84	0.175	0.062	Cylinder
T47	Blank	1968		2.83	2.16	0.92	0.147	0.065	Cylinder
L5	0.50 Graphite	2045	77	2.87	2.22	0.82	0.166	0.064	Cylinder
T47	Blank	1968		2.83	2.16	0.92	0.147	0.065	Cylinder
L9	0.50 Graphite	2037	59	2.85	2.36	0.81	0.162	0.050	Cylinder
L10	Blank	1978		2.82	2.39	0.82	0.143	0.062	Cylinder
L18	0.50 Graphite	2075	55	2.91	2.40	0.88	0.140	0.067	Wedge
L19	Blank	2020		2.92	2.46	0.91	0.117	0.067	Wedge

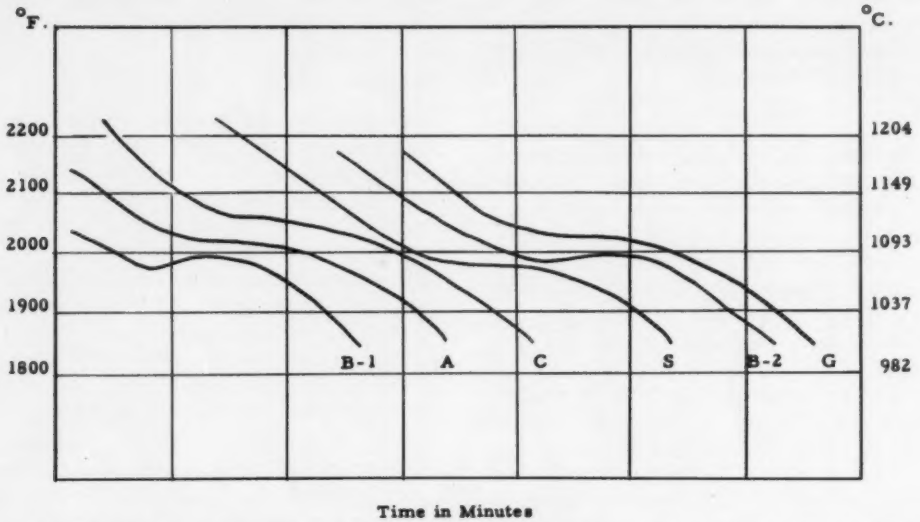

Fig. 1 — Comparison of typical cooling curves from cylindrical specimens. *B-1* — blank heat, not inoculated; *B-2* — blank heat, second series, not inoculated; *A* — inoculated with 0.6 per cent aluminum; *C* — inoculated with 1.0 per cent calcium; *G* — inoculated with 0.5 per cent fine graphite; *S* — inoculated with 0.55 per cent silicon.

fore include the difference introduced by this marked undercooling.

The elevation of temperature resulting from the addition of pure calcium was large, and for the three determinations ran 87, 70 and 75 F. Four curves for graphite were plotted and showed elevations of 52, 77, 59 and 55 F. Two determinations were made for the element silicon, and these curves exhibited elevations of 5 and 10 F. The amount of elevation produced by silicon additions in these experiments is a small fraction of that produced by the effective inoculants, calcium and graphite, and may be within the limit of experimental error.

Aluminum Additions

Two determinations were made for additions of aluminum. The amount of aluminum added was 0.60 per cent in both cases. The increase in eutectic temperature was 70 F for the first curve and 43 F for the second. This effectiveness of aluminum was surprising in view of the fact that aluminum additions produced no improvement of mechanical properties, and only a small and uncertain effect on the microstructure.

In these experiments the variation between duplicate determinations is large. Variations of a similar magnitude were obtained by Eash.[2] These variations may be a result of differences in the amounts of carbon, calcium or aluminum picked up by the molten iron, or to the critical conditions existing near the surface of the casting in the early stage of solidification.

That calcium and graphite, which are effective inoculants in the sense of improving graphite distribution, should elevate the eutectic temperature is in accordance with the accepted view that inoculation is a matter of nucleation of the eutectic cell formation accompanied by prevention undercooling and the promotion of type *A* graphite formation. However, the peculiar behavior of aluminum, which elevates the eutectic temperature without producing an improvement of properties and without producing type *A* graphite near the surface of the casting, makes it difficult to accept this simple explanation. Since aluminum, graphite and calcium are all effective in decreasing chilling tendency, it appears that there is a better correlation between nucleation, degree of undercooling and chilling tendency than between degree of undercooling and the formation of type *A* graphite.

Nucleation of Solidification and Transformation

During the course of the investigation to determine the influence of the addition agents on the eutectic temperature, a number of the wedge shaped castings previously described were quenched at the point on the time-temperature curve which indicated the start of eutectic solidification. This was done for the purpose of determining the state of solidification at this point on the curve, and in the hope that the transformation would be arrested in such a way by the accelerated cooling that effects of the various additives on the eutectic solidification would be revealed.

The quenching was accomplished by pouring the core sand mold for the wedge shaped casting over a water quench tank. At the proper moment during solidification, as indicated by the recording instrument, the mold was broken open and the partially solidified casting dropped into the quenching bath. After quenching, the castings were sectioned near the point where the thermocouple entered the iron and the sections were polished and etched with nital for the purpose of examining the microstructure and the macrostructure. The results of these experiments are presented in Figs. 2 to 8.

Figure 2 shows (left to right) the macrostructure

of Iron L21, treated with 0.55 per cent pure silicon; Iron T53-1, treated with 1.00 per cent calcium metal; and Iron T54-1, a blank or untreated iron. The round dark areas in the macrostructures of the silicon treated iron and the blank iron were revealed by the microscope to contain graphite, and to be centers of solidification and transformation of the eutectic in a background of primary dendrites. The area between the dendrites and the cells was in some places ledeburite and in others quench ledeburite, indicating that the quench had been at least partially successful in arresting solidification.

Examination of the microstructure of the calcium treated iron showed the numerous and small dark areas of the macrostructure to be eutectic solidification or transformation cells containing graphite. The large number of cells in the calcium treated iron, as compared with the silicon treated and the blank iron, indicates that calcium additions influence the degree of nucleation of the eutectic solidification either by providing nuclei or by activating already existing nuclei through an influence or interfacial energy. The similarity of the macrostructures of the silicon treated and the blank iron provides additional evidence that late additions of silicon are not effective in the case of hypoeutectic cast irons.

Nuclei Effect

It is evident that the size and rate of growth of the cells at a given time and for a given rate of heat extraction are functions of the number of nuclei. The extremely large size of the cells shown in these structures must be attributed to a certain balance between growth rate and nucleation rate brought about by the accelerated cooling produced by the quench. Such extremely large cells are not found in irons solidified in the normal manner.

Examination of the microstructure of the small cells of the calcium treated and quenched specimens disclosed the presence of large graphite flakes of the *A* type in the center of the cells in a background of tempered martensite and retained austenite. Figure 3 shows one of these cells with several light gray, graphite flakes in the center of the picture at 500×. The photomicrograph also shows some extremely fine graphite at the periphery of the cell, presumably formed during the quench since this type of graphite is not found in the normally cooled irons.

The transformation cells appear dark in the macrostructures because of the presence of graphite, and of the absence of massive cementite. The amount of retained austenite is also less in the vicinity of the graphite flakes. The large cells in the untreated and the silicon treated irons were found to contain graphite flakes, varying in size and distribution with a strong tendency towards types *D* and *E*, as opposed to the type *A* flakes in the centers of the cells of the calcium iron. The cracks and other defects showing in the macrographs are a result of quenching in the partially liquid condition.

Figure 4 shows macrographs of L19 (left) a blank or untreated iron, and of L18, treated with 0.50 per cent graphite in the ladle (right). Iron L19 has the large cells that were typical of all of the untreated

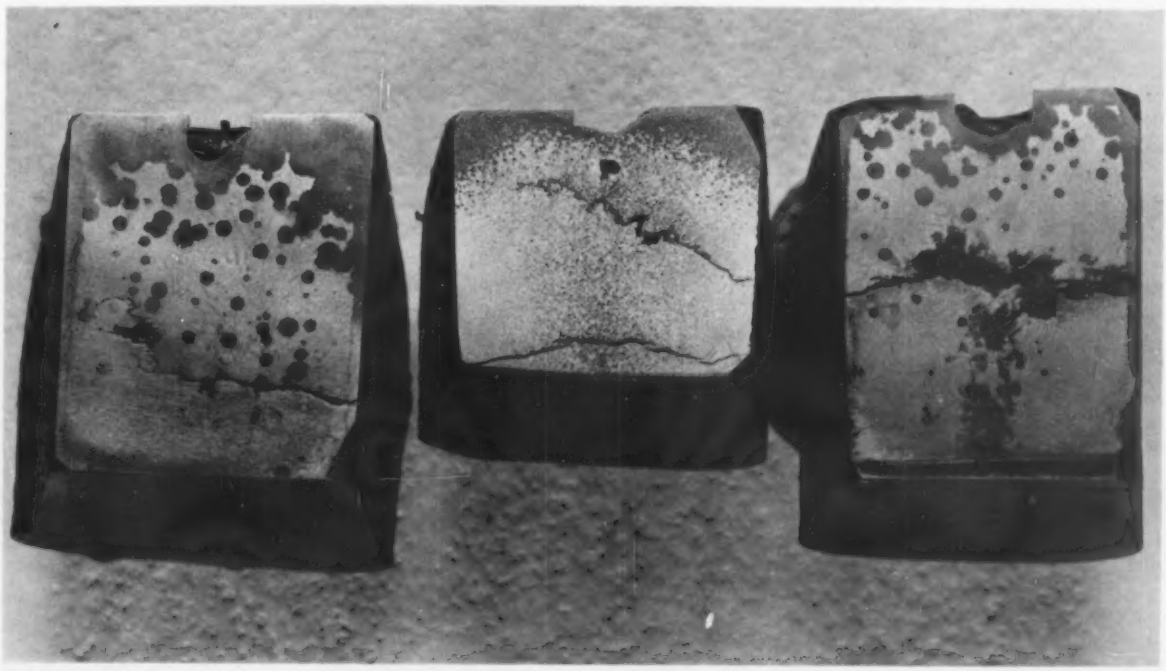

Fig. 2 — Macrostructures of irons quenched at start of eutectic solidification. *Left to right* — iron L21, treated with 0.55 per cent pure silicon; iron T53-1, treated with 1.00 per cent calcium metal; iron T54-1, blank or untreated iron. Note large number and small size of transformation cells in calcium treated iron as compared with silicon treated and blank irons. Similarity of silicon treated and blank iron indicates lack of nucleating effect of late additions of silicon. Magnification approximately 2 ×. Nital etch.

Fig. 3 — Microstructure of transformation center of iron T53-1 treated with 1.00 per cent calcium and quenched at start of eutectic solidification. Type *A* graphite flakes are developing at the center, surrounded by extremely fine graphite presumably formed during the quench. 500 ×. Nital etch.

irons examined in this manner. The graphite treated iron exhibits a large number of small cells, indicating a nucleating effect in keeping with the influence of the graphite addition on the microstructure and properties of the iron. Examination of the individual cells of Iron L18 showed them to contain large flakes tending towards the type *A* distribution.

Figure 5 shows the microstructure of an individual cell at 100 ×, and displays a cluster of type *A* flakes in martensite with a ring of fine graphite, apparently formed during the quench. The balance of the structure is primary dendrites and quench ledeburite.

Figure 6 pictures the macrostructures of Iron L27-3, treated with 0.50 per cent aluminum (left) and of the corresponding blank iron from the same heat (right). The aluminum treated sample shows many small centers, and indicates that aluminum additions are effective in some way in influencing the nucleation of the eutectic transformation when the rate of cooling is accelerated. This result was surprising in view of the inability of the aluminum addition to produce type *A* graphite at the surface of the casting, and the failure of the aluminum additions to bring about an appreciable alteration of transverse properties.

Microexamination

Examination of the microstructure of the individual cells of the aluminum iron revealed them as containing extremely fine graphite with a pronounced interdendritic distribution. The photomicrograph of Fig. 7 shows a number of these cells with a typical cell at the center of the picture. Note the fine graphite, which is only partly resolved at 100 ×, and is only

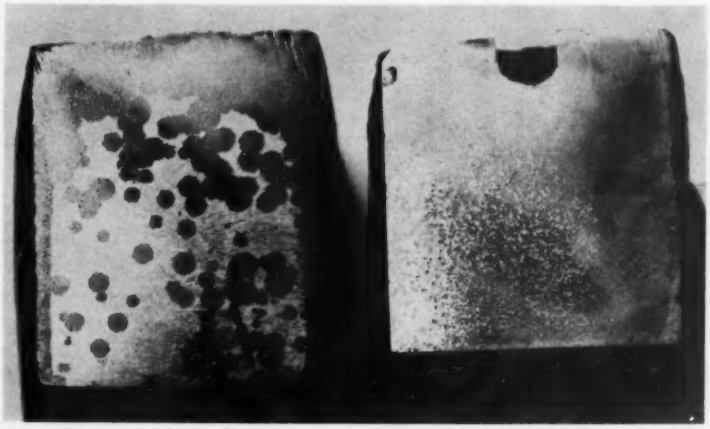

Fig. 4 — Macrostructures of irons quenched at start of eutectic solidification. *Left* — iron L19 blank or untreated iron; *right* — iron L18 treated with 0.50 per cent graphite in ladle. Note large number of dark transformation centers produced by the graphite addition as compared with the small number of large centers in the untreated iron. Magnification approximately 2 ×. Nital etch.

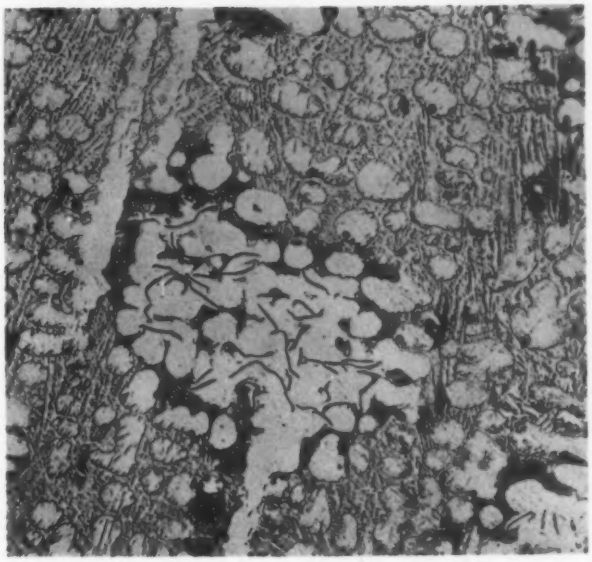

Fig. 5 — Microstructure of transformation center of iron L18 treated with 0.50 per cent graphite in the ladle and quenched at the start of the eutectic solidification. Type *A* graphite is in martensite at the center, surrounded by extremely fine graphite at the periphery. Balance of the structure is primary dendrites and quench ledeburite. 100 ×. Nital etch.

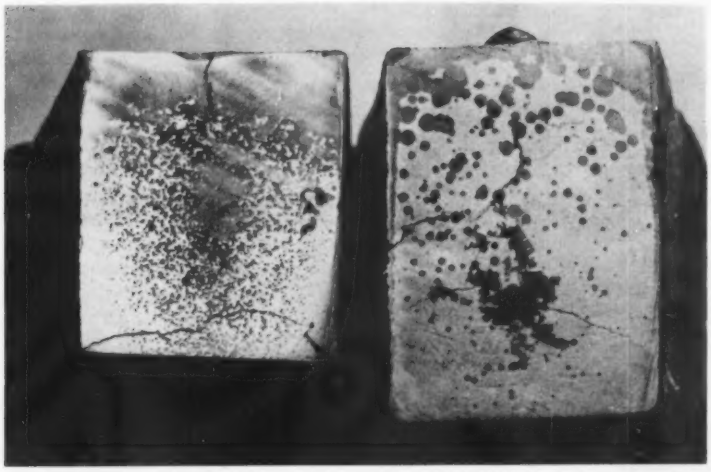

Fig. 6 — Macrostructures of irons quenched at start of eutectic solidification. *Left* — iron L27-3 treated with 0.50 per cent aluminum; *right* — corresponding blank or untreated iron from same heat. Note large number and small size of dark transformation centers in the aluminum iron as compared with blank iron. Magnification approximately 2 ×. Nital etch.

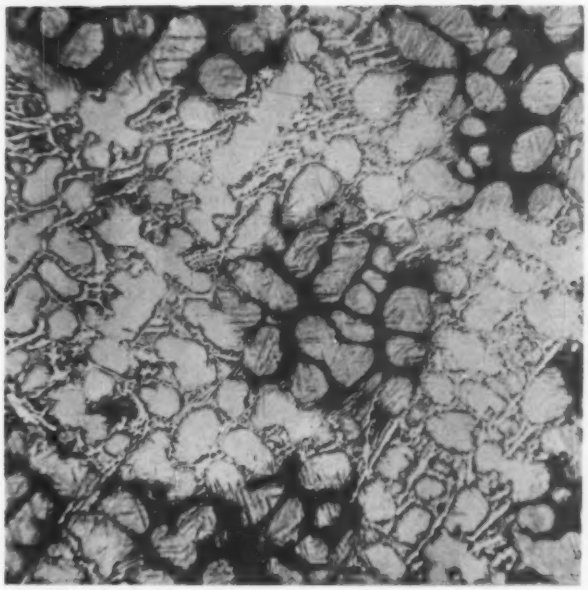

Fig. 7 — Microstructure of transformation center of iron L27-3 treated in the ladle with 0.50 per cent aluminum and quenched at start of eutectic solidification. Note interdendritic distribution of extremely fine graphite and absence of type A graphite. 100 ×. Nital etch.

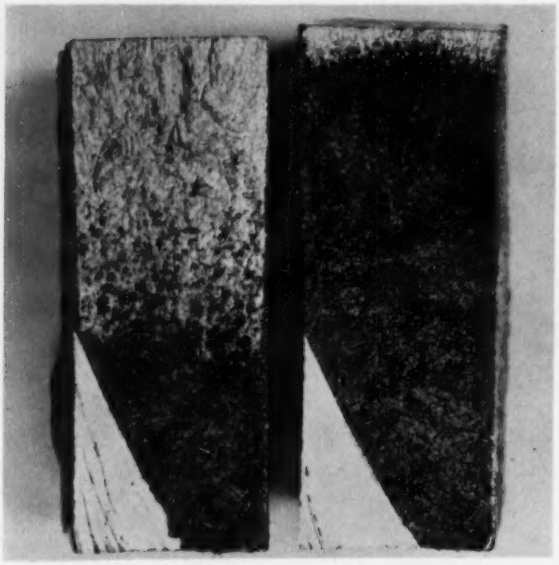

Fig. 8 — Chill block fractures showing influence of aluminum addition on chilling tendency. *Left* — iron L27-3, the blank or untreated iron; *right* — iron L27-4 treated with 0.50 per cent aluminum.

partly retained. The balance of the structure is made up of primary dendrites and quench ledeburite.

From these results for aluminum additions, it would appear that it is possible for an additive to nucleate the eutectic solidification and elevate the eutectic temperature without producing type *A* graphite in zones where there is accelerated cooling such as exists at the surface of a casting. It is also indicated that a certain type of nucleation is essential to the formation of large, random flakes. Various investigators have argued that large flakes result from the slow cellular growth, which takes place when the cells are numerous as a result of a nucleation. The solidification behavior of the aluminum irons makes it difficult to accept this explanation without reservation.

Figure 8 is a picture of the fractures of chill blocks for Iron L27-3 (left) and Iron L27-4 (right). Iron L27-4 was treated with 0.50 per cent aluminum, and Iron L27-3 is the corresponding blank from the same heat. The marked influence of aluminum in reducing chill is evident. The extensive mottled zone of the untreated irons is typical of all the untreated irons of this investigation. The large and numerous islands of gray fracture in the mottled zone appear to be correlated with the large transformation cells of the quenched irons.

It is suggested that the extent and character of the mottled zone of the chill block may serve as a measure of the degree of nucleation of the eutectic solidification. It also appears that the correlation between the degree of nucleation and chill depth is better than the correlation between the degree of nucleation and the graphite distribution. It is indicated that the degree of nucleation of graphite formation may be a more important factor in determining chill depth than is an inherent stability of the carbide phase.

SUMMARY AND CONCLUSIONS

The conclusions are based on experiments with hypoeutectic, induction and indirect arc furnace high strength irons. These irons were selected because of their tendency towards unfavorable graphite distributions, and because of their sensitivity to late additions. This is presented as a progress report, and the authors feel that more data are required, particularly in the case of aluminum treatment, before final conclusions about some of the additions are justified.

Specific conclusions and observations from this report are:

Late additions of pure silicon to hypoeutectic cast irons were not effective in altering the properties or microstructure in a favorable manner. Late additions of silicon to hypoeutectic irons did not elevate the eutectic temperature appreciably as compared to the other elements investigated, and did not nucleate the solidification of the eutectic liquid. Late additions of silicon did not bring about an appreciable reduction of chilling tendency when treated and untreated irons were melted to the same final composition.

Late additions of metallic calcium produced a marked improvement in graphite distribution and mechanical properties of hypoeutectic gray cast iron. Calcium, and high calcium-silicon alloys were the most effective inoculants for cast iron investigated in this research. Calcium was effective in reducing the chilling tendency. Calcium was the most effective element in elevating the eutectic temperature, and was effective in nucleating the solidification of the eutectic.

Ladle additions of graphite produced an improvement in mechanical properties and in graphite distribution. The addition of graphite effected a marked reduction of chilling tendency when the graphite treated irons and the untreated irons for comparison were melted to the same final composition. Graphite additions were effective in elevating the eutectic temperature. Graphite additions were effective in nucleating the eutectic solidification.

Late additions of aluminum were not effective in improving the transverse properties of hypoeutectic gray cast iron. Aluminum additions did not produce type *A* graphite in the rapidly cooled zone adjacent to the surface of the 1.2 in. standard transverse bar. Aluminum additions were effective in reducing chilling tendency. Aluminum additions elevated the temperature of eutectic solidification, and were effective in increasing the number of centers of eutectic solidification.

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ALUMINUM ALLOY DIE CASTING

Outline of British practice

by R. R. Woodward and H. J. Proffitt

ABSTRACT

The authors draw comparisons between the different trends in Britain and the United States with regard to the use of the gravity and pressure die casting processes. The predominance of the pressure process in the U.S.A., and of the gravity method in Britain is noted, and some of the underlying reasons for this are described. The factors influencing the choice of each method in Britain, including costs, surface finish and dimensional accuracy, are illustrated.

Current British pressure die casting practice with regard to machines, die design and manufacture and alloys used, are described.

Current gravity die casting methods are reviewed, including means for improving the rate of output by a) mechanization, b) increasing yield per casting, c) use of multi-impression dies and d) economic use of solidification dwell time, are discussed.

The British alloys used in the gravity process are reviewed, and modern methods of metallurgical and foundry control and future development trend, are mentioned.

INTRODUCTION

In Britain, foundry terminology is slightly different to that in current use in the U.S.A. We use the term "die casting" as an overall description embracing both pressure and gravity die casting. You refer to the latter as "permanent mold" casting, and pressure die casting simply "die casting." It is the authors' intention, therefore, to deal to some extent with both of the die casting processes being used in Britain.

FACTORS INFLUENCING CHOICE OF PRESSURE OR GRAVITY DIE CASTING PROCESS

Economic Considerations

Figures 1 and 2 show the tonnage figures for total casting production of Britain compared with the U.S.A. for sand, gravity and pressure die castings for the years 1949 to 1957.

Several interesting points are noted. Total annual production shows the same increasing trend in both countries. In the United States, pressure die casting represents a substantial part of the total production throughout, and indeed from 1954 onwards, became the largest producing method.

In Britain, by contrast, however, the major production method has been gravity die casting by a substantial margin, in spite of a significant increase in pressure die casting.

The authors do not intend to deal to any extent with the reasons for these differences, but the figures do tend to throw more light on the following points:

1) In Britain some castings which would in America be regarded as naturals for pressure die casting, are, in fact, designed for and produced by the gravity method.
2) Nearly half of the total casting production in Britain goes into the automotive industries, a pre-

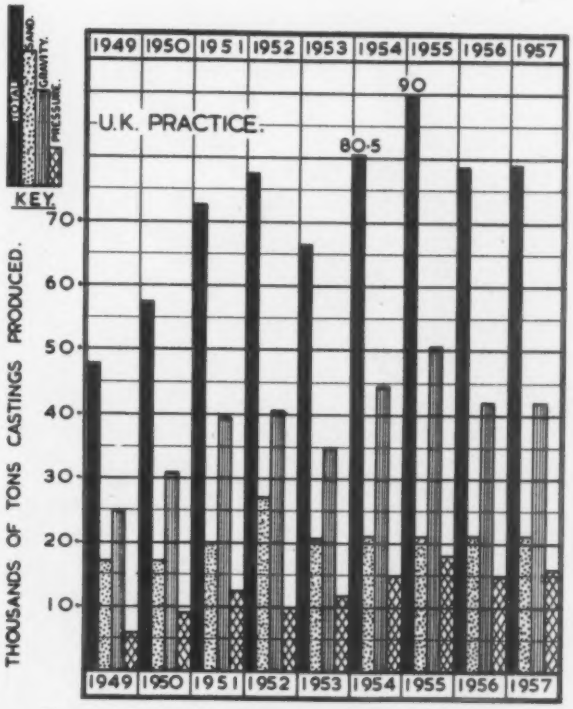

Fig. 1 — Comparison between yearly production of aluminum gravity, pressure and sand castings in Britain.

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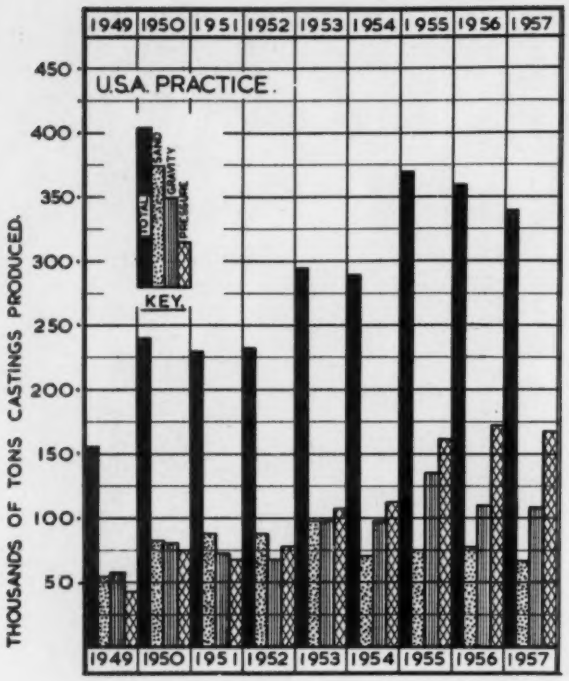


Fig. 2 — Comparison between yearly production of aluminum sand, gravity and pressure die castings in the United States.

dominant amount of these being produced by the gravity method. The main reasons for this are economic.

The deciding factor when choosing between a gravity or pressure die casting for incorporation in a salable commodity, providing all functional requirements are satisfied, is cost.

Pressure die casting cannot be justified unless the "call off potential" is large enough to permit satisfactory amortization of the extremely high cost of dies, and capital equipment when compared with the gravity process.

The great difference between "call off potential" in the U.S.A. and in Britain is reflected in the figures for total casting production in Figs. 1 and 2. This is probably the fundamental reason for the difference in design outlook and in process usage.

Surface Finish

One of the main reasons for choosing the pressure die casting process for the production of a given casting is the desire for good surface finish, consistent with the economic and functional considerations. The surface finish on pressure die castings is superior to that which can be obtained by gravity die casting.

In fairness, however, it should be added that with gravity die castings using the latest techniques of careful die making and foundry control, good surface finish can be obtained which is adequate for most purposes.

One of the main deterrents to the production of good surface finish and exact reproduction of the die form of both types of die casting is the air in the die which cannot be completely expelled in advance of the incoming metal. With modern processes and machines this effect is reduced to an absolute minimum, but it still constitutes one of the main reasons why the evacuation of the die is being regarded as a necessary development.

Dimensional Accuracy

The dimensional accuracy considered possible economically by the pressure die casting process is much better than can be obtained from the best gravity die casting method.

In Britain, the dimensional tolerances now generally accepted as being economically practicable for the pressure process have been published by Z.A.D.C.A.* and are summarized:

Pressure Die Casting Tolerances. For critical dimensions, tolerances for dimensions unaffected by parting lines or moving die parts are:

Basic tolerance up to 1 in. on linear dimensions	± 0.003 in.
Additional tolerance for each additional in.	± 0.0015 in.

When the dimensions in a single impression are affected by a parting line or a moving die part, an additional tolerance is allowed dependent upon the "projected area" of the casting.

Similarly, standards exist for flatness, which allows for tolerances of 0.008 in. for casting with maximum dimensions of 3 in. diameter or diagonal dimension with an additional tolerance of 0.003 in. for each additional in.

Gravity Die Casting Tolerances. For normal economic production general tolerances are ± 0.010 in. up to 3 in. with an additional tolerance for each additional in. of ± 0.002 in., where unaffected by parting line or moving die part. Where a given dimension is affected by a moving die part, an additional tolerance is allowed of ± 0.010 in.

Tolerances applicable to surfaces formed by Sand, CO_2 or Shell Cores are ± 0.015 in. up to 3 in., with an additional ± 0.002 in. for each additional in. Machining allowance is normally 0.025 in. per surface for pressure and 0.062 in. for gravity. Additional allowance due to taper is kept to a minimum to avoid

**Engineering Standard for Pressure Die Casting*, Zinc Alloy Diecasters Assoc., London.

the necessity for deep penetration below the skin of the casting.

GRAVITY OR PRESSURE?

The cost of producing say 100,000 of one typical gravity die casting will certainly be higher than if the pressure method was used.

With normal gravity processes, although the cost of the die is quite low compared with pressure, the cost of casting is much higher.

In Britain, the modern trend with gravity where the number of castings required warrants it, is to reduce cost per casting by die mechanization to approach more nearly that of pressure die cast production.

The technical limitations which sometimes rule against the use of the pressure process, even though numerical requirements are satisfied, are:

a) The need for a wider choice of alloy.
b) The necessity for heat treatment to develop optimum mechanical properties.
c) The need for decorative anodic treatments.
d) The need for guaranteed internal soundness.

The pressure die cast design will almost certainly weigh less than if produced by gravity method, thus indirectly reducing cost.

It is only by good technical control that castings of a reliable nature can be supplied to a differentiating market.

CURRENT BRITISH DIE CASTING PRACTICE AND PROBLEMS

The pressure die casting process offers every opportunity for full automation, even to autoladling of the metal, although this has not as yet become widely used in Britain. Speed of production, however, is improved whenever possible by the use of:

1) Modern equipment and machines with semiautomatic cycling.
2) Automatic lubrication of plunger and die face.
3) Jig trimming, fettling (cleaning) and improved handling devices.
4) Stricter control of the casting variables, such as metal and die temperatures, etc.
5) By employing multi-impression dies.

Pressure Die Casting Machines

In general, aluminum alloys are cast on cold chamber machines which vary from small (about 50 tons) to large machines of 1200 tons locking capacity. The types in use include those of practically every well known manufacture in the world, while some larger foundries build to their own particular requirement.

Most of the machines in the larger foundries are to be found within the 75 to 500 ton locking capacity range. Above 500 ton size machines become scarce as size increases. In self-contained machines with their own hydraulic pumps, oil is normally used as the hydraulic medium with gas bottle accumulators to boost plunger speed. Nonflame oils are not yet used to any appreciable extent, and consequently great care with design, machine installation and safety precautions is imperative.

Water-hydraulic machines are still used extensively, usually in groups supplied from a central pumping installation with plunger speed boosted by either a single large "dead weight" accumulator stationed at the pumps, or gas bottle accumulators with each machine.

Machines with vertical injection units are still used extensively, especially for brass, but this type is becoming less popular due to problems of plunger and chamber wear.

The well known 3-phase injection action has for years been considered advantageous for the production of high quality castings under normal conditions, and high metal pressures of 15,000 to 30,000 lb/sq in. are commonly used during the third stage. These pressures reduce to microscopic proportions any air entrapped in the metal during the second stage.

The die cavity must be filled as quickly as possible if the tendency to cold shuts, etc., are to be overcome. Prior to the recent developments in the field of vacuum pressure die casting, injection speeds have been somewhat limited in order to minimize air entrapment. Hitherto careful attention to die design, especially with regard to gates, vents and overflow wells, has been the only way in which die designers could cater for high injection speeds.

Injection Plunger and Chamber Wear in Cold Chamber Machines

The need on modern cold chamber machines in Britain is that of overcoming plunger and chamber wear and the downtime ensuing from it. Of many materials tried nitrided steel is preferred for these parts, provided the hardness of the core material is sufficient. However, careful optical measurements, and study of the relative movements of each machine part involved in the injection stroke, has shown that most of the problems of plunger and chamber wear can be traced back to basic machine design.

The injection unit must not move out of correct relationship with the fixed platen under the application of the high injection forces. The provision of a self aligning coupling consisting of a hardened hemispherical knuckle joint is not sufficient, since this becomes virtually locked in its start position under the application of high injection loads.

Correct axial alignment of plunger and chamber is vital, and machine designers should reconsider the method of attachment of the injection unit to the rear of the fixed platen to ensure positive alignment and the need for self-aligning couplings should be obviated.

One of the major problems on vertical injection type machines is that caused by the sprue bush expanding into the chamber bore. This can be partially cured by making an expansion allowance, but a more effective cure is shown in Fig. 3. A flat is machined on the outside of the chamber around

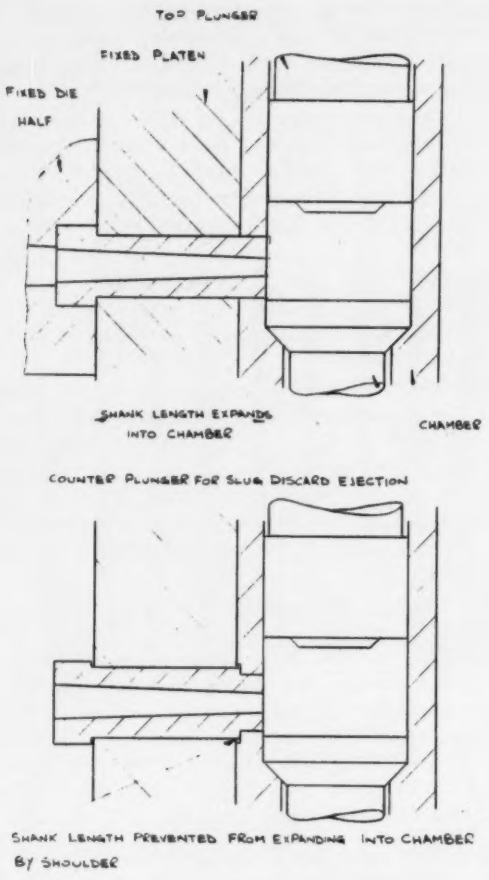

TOP PLUNGER
FIXED PLATEN
FIXED DIE HALF
SHANK LENGTH EXPANDS INTO CHAMBER
CHAMBER
COUNTER PLUNGER FOR SLUG DISCARD EJECTION
SHANK LENGTH PREVENTED FROM EXPANDING INTO CHAMBER BY SHOULDER

Fig. 3 — Method of preventing rapid plunger and chamber wear on machines with vertical injection.

the hole for the sprue bush. The sprue bush is redesigned to have a stepped shank, and when fitted into the machine the stepped shank butts against the flat on the side of the chamber and prevents the end expanding into the internal bore of the chamber.

Die Design and Manufacture

For a given type and size of casting, dies designed and manufactured in Britain tend to be much smaller than those in the U.S.A., because fewer of the larger machines are available. The tendency in Britain is towards overloading the machine, and large dies often have to be carefully tailored to clear the tie bars and overhang the edges of the platens. To set these large dies on the machine often necessitates the removal of tie bars. Solid frame machines are not, therefore, as popular in Britain as in the U.S.A.

The fixed die half for a typewriter frame is shown in Fig. 4 being lowered into position on an 800 ton machine, with the top two tie bars retracted to facilitate die setting. Figure 5 shows the die in production and the tailoring of the die around the tie bars.

Wherever possible expensive die steels are only used for the impression blocks, which are confined in size to provide just sufficient accommodation for casting impression, overflow wells and a reasonable amount of shut off around the peripheral shape of the casting. These impression blocks are housed in die blocks of a cheaper steel, which can be mild steel or medium alloy steel according to required call-off.

The duplex character of a typical die is indicated by the chalk outline in Fig. 6.

A typical die steel in common use for pressure dies for aluminum is of the following composition:

C, %	Si, %	Cr, %	Mo, %	Va, %
0.4	0.8	5	1.5	1

This type of steel has a good resistance to metal erosion and heat checking, with good elevated tem-

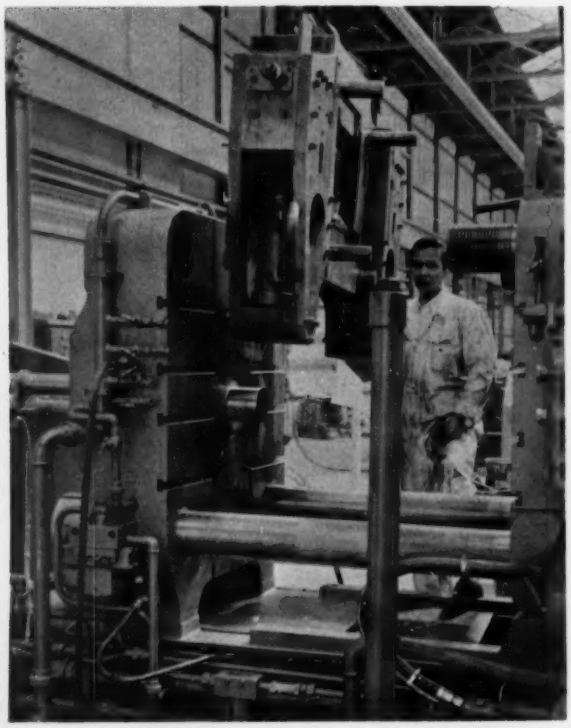
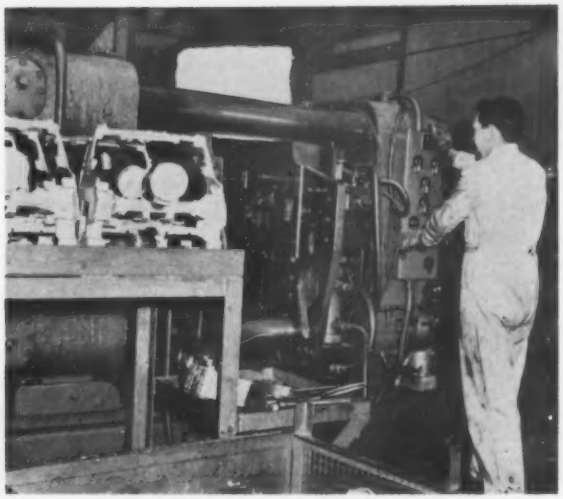


Fig. 4 — Die half being lowered into position on machines with top tie bars retracted.

Fig. 5 — Typewriter die in production on 800 ton machine.



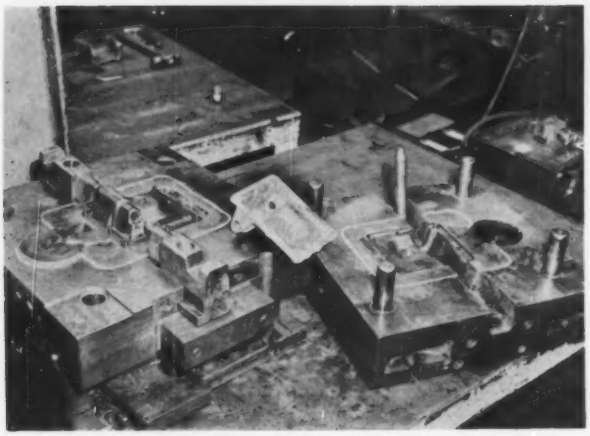


Fig. 6 — Die for gear box end cover illustrating relative size of impression blocks. The duplex character of a typical die is indicated by the chalk outline.

perature properties and machinability. Heat treatment is simple with minimum distortion, and die parts are normally treated to a hardness of 42-48 Rockwell C.

Core pin failure is troublesome and not always due to carelessness. The above type of die steel, in the heat-treated condition is not completely satisfactory for this purpose, and a stainless steel of nominal composition 13 per cent Cr, 0.18-0.25 per cent C, 0.1 per cent Mn and 0.1 per cent Si, has been found to give a greater life used in the unhardened condition.

Steels with appreciable tungsten contents are nowadays seldom used, except for pressure die casting brass. This type of steel is prone to stress corrosion cracking and premature die failures have occurred.

To enable castings with a lower call-off potential to be made by reduction in tool costs, a system of die design has been evolved, based on the use of standardized die impression block housings which accommodate interchangeable impression blocks.

The advantage of this system lies in the fact that if it is possible to accommodate the design of the casting in impression blocks that fit into these standard housings, then the tooling charges will only be that of the impression blocks plus a simple ejector system and not of a complete die. The impression blocks are designed so that they can be fitted or removed without disturbing the housing on the machine. Fig. 7 shows the method of fastening the impression blocks in position in a standard housing for a 200 ton machine.

For the production of long tube-like castings, which require large flanges at one or both ends with flat outer faces, a simple method of two-stage core withdrawal has been evolved.

Figures 8 and 9 show a method of incorporating a two-stage core withdrawal by the use of an angle pin to first pull the long core which forms the bore. A side slide, which forms the flat outer face of the flange and provides stripping, is held in position to support the flange by a core withdrawal hydraulic cylinder during this operation. After the

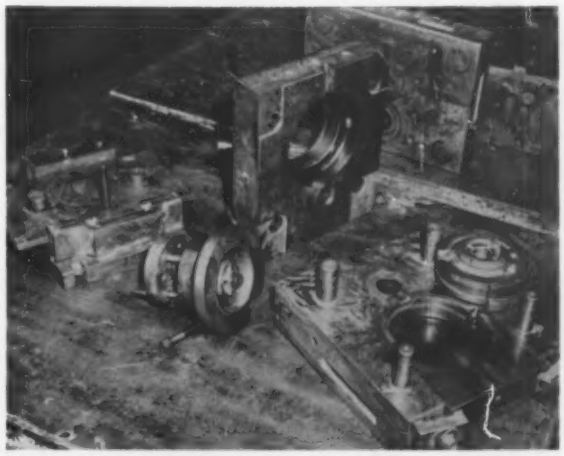


Fig. 7 — Exploded view of die employing common housing.

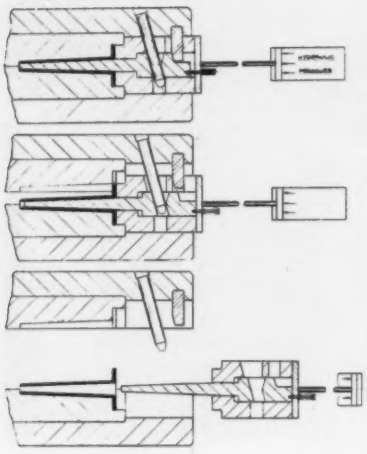


Fig. 8 — Two-stage core removal for long slender cores. *Top* — die closed; *center* — die partly opened, inner core withdrawn, outer core still held by core lock; *bottom* — die fully opened, cores withdrawn hydraulically. Arrows show direction of hydraulic pressure.

long core is released from the casting, the main side slide is drawn and the casting ejected in the normal manner.

PRESSURE DIE CASTING ALLOYS

As in the United States, there exists in Britain a system of national specifications covering accepted castings alloys. These are designated B.S.1490 and formulated by the British Standards Institution in close collaboration with the industry.

In these specifications, various grades of pure aluminum and aluminum alloy are given numbers prefixed by the letters LM ranging from 1 to 24. The conditions in which castings in these alloys may be obtained are shown by the suffixes:

As cast ..... M
Solution heat treated only ..... W
Precipitation treated only ..... P
Solution treated and
Precipitation treated ..... WP

BRITISH SPECIFICATIONS & NEAREST AMERICAN EQUIVALENTS.

BRITISH STANDARD 1490	A.S.T.M. EQUIVALENT	NOMINAL COMPOSITION. % Si	% Cu	% Mg	% Mn	OTHERS	% MAX USED FOR GRAVITY G OR PRESSURE P	VALUES WHETHER HEAT TREATED
LM.1.	——	3·0	7·0	——	——	Zn 3·0	G	NO
LM.2.	——	10·0	1·5	——	——	Fe 1·0 + Zn 1·2 +	P	NO
LM.4.	SC.54.A&B	5·0	3·0	——	0·5	Zn 0·4	G+P	YES
LM.5.	G. 4A	——	——	5·0	0·5	——	G	NO
LM.6.	S.12A	11·0	0·1	0·1	——	Fe 0·6 + Zn 0·1 +	G+P	NO
LM.7	——	2·25	1·5	0·1	——	Zr 1·0 Fe 0·2	G	NO
LM.8.	——	5·5	——	0·5	——	——	G	YES
LM.9.	——	11·5	——	0·4	0·5	——	G	YES
LM10.	G.10.A	——	——	10·5	——	——	G	YES
LM12	CG.100A	——	9·75	0·25	——	Fe 1·0	G (PISTONS)	YES
LM.13.	SN.112.A	12·0	0·9	1·2	——	Ni 2·5	G (PISTONS)	YES
LM.14.	CN. 42.A	——	4·2	1·5	——	Ni 2·0	G	YES
LM15	——	0·75	1·5	0·8	——	Zr 1·0 Fe 0·2	G	YES
LM.16.	SC. 51A	5·0	1·25	0·5	——	——	G	YES
LM18.	S5. A,B & C.	5·0	——	——	——	——	G	NO
LM.20.	S.12. A	11·5	0·4	0·15	——	Fe 0·7 + Zn 0·2 +	G+P	NO
LM.21.	——	5·0	3·0	——	0·5	Zn 2·0+	G	NO
LM.22	——	5·0	3·3	0·05*	0·45	Zn 0·13 + Ni 0·15 + Fe 0·7 +	G	YES
LM.23.	——	2·5	1·0	0·10	——	Zr 1·0 Ni 1·0 Fe 0·2	G	YES
LM24	(SAE 306)	8·5	3·5	——	——	Fe 1·3 Zn 1·0	P	NO

Fig. 10 — British specifications and nearest American equivalents. It should be pointed out that many important American alloys have been omitted as they have no real British equivalent.

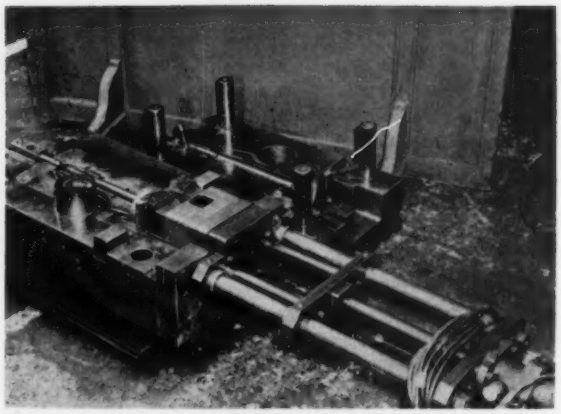


Fig. 9 — Die showing two-stage withdrawal method.

The B.S.1490 range of alloys, which find use for both die casting processes are shown in Fig. 10, together with their nearest American equivalents and the casting methods normally used and whether heat treatable in gravity die cast form.

In explanation, it should be pointed out that Fig. 10 is only intended to show where direct American equivalent of alloys used in the U.K. exist. In doing so many important American alloys have been omitted because they have no real British equivalent. It can be seen from this list that although many of the alloys are normally used for casting by the gravity process, only a few of those shown are normally cast by the pressure die casting process.

A large proportion of both gravity and pressure die castings is in a relatively small number of alloys. It is not normal British practice to employ more than a fairly low temperature stress relieving heat treatment to pressure die castings which, unlike gravity die castings, are always used in the as-cast condition.

Alloys Containing Silicon

Manufacturers of aluminum alloy pressure die castings prefer the alloys containing silicon at or about the eutectic composition since these are well known to be among the most fluid.

* MAX. VALUES.

SPECIFICATION IDENTITY BS 1490	NOMINAL COMPOSITION %					TYPICAL TENSILE PROPERTIES OF STANDARD GRAVITY DIE CAST TEST BARS.				CHARACTERISTICS						
	Si	Cu	Mg	Mn	OTHERS	0.1% PROOF STRESS TONS SQ" PSI	TENSILE STRENGTH TONS SQ" PSI	ELONG' IN 2" GL	BRINELL HARDNESS	CASTIBILITY	STRENGTH	SHOCK RESISTANCE	SERVICE TEMP LIMIT °C	MACHIN-ABILITY	RESISTANCE TO ATMOSPHERIC ATTACK	TYPE OF ANODIC FILM
LM2 M	10·0	1·5	—	—	Fe 1·0 * Zn 1·2 *	6·0 13,500	13·0 29,000	2·0	80	V.GOOD	MED.	F.LOW	150	GOOD	FAIR	—
LM6M	11·0	0·1 *	0·1 *	—	Fe 0·6 *	4·5 10,000	13·5 30,500	10·0	60	GOOD	MED.	F.HIGH	"	FAIR	F.GOOD	—
LM24M	8·5	3·5	—	—	Fe 1·3 Zn 1·0	6·0 13500	13·0 29,000	3·0	85	V.GOOD	MED.	F.LOW	"	GOOD	FAIR	—
LM5M	—	—	5·0	0·5	—	5·0 11,000	11·0 24,500	5·0	65	SPEC. TECH.	MED.	F.HIGH	—	F.GOOD	GOOD	—
LM 4M	5·0	3·0	—	0·5	—	4·5 10,000	11·0 24,500	3·0	75	F.GOOD	MED.	FAIR	150	GOOD	FAIR	—
LM20M	11·0	0·4 *	0·15 *	—	Fe 0·7 *	4·5 10,000	13·5 30,500	7·0	60	GOOD	MED.	F.HIGH	"	FAIR	FAIR	—

Fig. 11 — Aluminum alloys used for pressure die casting.

For this reason the most popular alloy is the LM 2M, composition shown in Fig. 11. The alloy contains, in addition to silicon, 1.5 per cent of copper and tolerances for most of the normal impurities which arise incidental to the alloys manufactured from secondary material.

It is not normal to degas the molten alloy or to modify it for pressure die casting, and no precautions, other than ensuring general cleanliness and compositional homogeneity, are required. The alloy possesses good rigidity, although the corrosion resistance and ductility are low. It also machines well.

When castings, having particularly large areas of thin section are required, it is normal to use the LM 6M type alloy, which has a higher silicon content and a higher fluidity than LM 2M and no intentional copper impurity.

The LM 6 alloy is slightly more difficult to cast, and because of its greater purity is more expensive. It is not as easy to machine as the copper containing version, and relatively heavy sections appear to be more prone to local sinks.

A further alloy which is pressure die-cast less frequently is designated LM 5M, and has even better corrosion resistance with higher mechanical properties. LM 5M is fairly difficult to cast and control in the foundry, and requires a special melting technique similar to that described later for the alloy LM 10W, containing 10 per cent of magnesium, and care to avoid contamination must be exercised. Although this type of alloy in other cast forms is readily anodizable, producing a clear anodic film, pressure die castings are not normally treated in this matter as the anodic attack reveals unpleasing surface irregularities.

Alloy LM 24M

The alloy LM 24M, which is of American origin, is now being used to an increasing extent, being specifically developed for the process. It has a lower silicon and higher copper content than the LM 2M alloy, and also possesses high iron and zinc impurities.

In LM 24M, iron can be regarded more as an alloying element than an impurity, since it gives an improved surface finish and eliminates any tendency for local welding to the die and results in higher output rates.

Two further alloys in the B.S.1490 range, LM 4 and LM 20, are also pressure die cast periodically. LM 4M is described later, while the alloy LM 20M is similar to LM 6M with wider impurity limits and, therefore, cheaper.

GRAVITY DIE CASTING

Due to the high demand for gravity die castings in Britain, foundries have concentrated their efforts towards speeding up and improving the process by a careful appraisal of all of the technical and economic factors involved. Developments have included:

a) Increased production rates by means of die mechanization.

b) Increase in the yield per casting cycle by reduction in remelt ratio and the use of multi-impression dies.

c) Economic use of solidification dwell time.

Mechanization

Whenever the call-off is large enough, the casting cycle time is shortened by the application of hydraulic or pneumatic methods of die manipulation to reduce manual effort and minimize skill required.

Most of the mechanization is simply substitution of hydraulic or pneumatic cylinders for the manual method of opening and closing die blocks by means of racks and pinions, the cylinders being normally controlled by the operator using hand or foot operated valves.

This type of mechanization can be seen in Fig. 12, which shows a die mounted on a standard bench which has facilities for varying the height and location of the cylinders to suit various sizes of die.

Large top cores are guided and actuated by means of cylinders supported by superstructure over the die reducing manual handling. Power ejection also facilitates easy removal of castings from the die. Figure 13 shows an example of such a semi-mechanized die for producing a washing machine wringer base. In most cases powered die movements are interlocked to prevent out of sequence operation which can cause die damage.

Figure 14 shows two pneumatic machines in operation actuating small single impression gravity dies produced castings each weighing ½-lb. These particular machines each reproduce, in correct sequence, what would otherwise require 16 core and die movements on the part of each operator per cycle, and

Fig. 12 — Standard bench for use of operating semi-mechanized gravity die.

Fig. 13 — Semi-mechanized gravity die producing a wringer base for a washing machine.

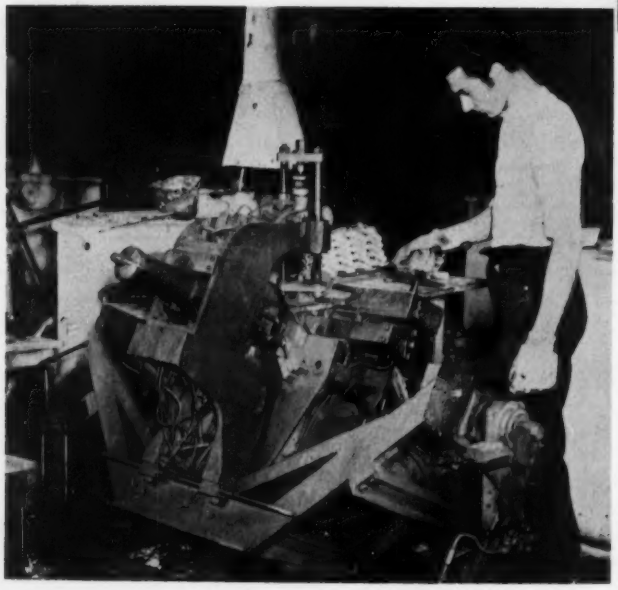


Fig. 14 — A fully automatic die casting machine operating on pneumatic principle.

Fig. 15 — Improved riser efficiency by use of shell core riser insulation.

each have production rates in excess of 100 castings/hr.

To remove the human element, and prevent the tempo of production remaining subject to the human element, electronic and pneumatic timers are used extensively to control the solidification dwell and to initiate the sequence of other die movements.

Thermal insulation of the power cylinders from the hot parts of the die is essential to prevent damage to the cylinder packings, and a means for rapid uncoupling of die parts from the cylinders, has proved necessary to allow re-application of die dressings which wear off quickly.

Increase in the Yield per Casting Cycle and Multi-Impression Dies

Reductions in the number and size of risers are possible by the application of progressive feeding techniques, whereby the direction of solidification is controlled. This is achieved by hastening or delaying solidification in various parts of the casting and risers. For example, the thickness of the die adjacent to a riser can be appreciably increased to provide a mass to absorb and hold some of the heat continually being put into the die, and this increases the riser efficiency.

The die is considered as a heat exchanger, in which the heat content of the metal must be extracted to allow solidification to take place. Heat transferred from the solidifying casting must either dissipate through the die's exposed radiating surfaces, or be conducted away by the application of a cooling medium. Certain die parts are designed with large mass in comparison with radiating surface, their capacity for absorbing and holding heat being increased.

High production rates quickly fill this thermal capacity, and the thick part then has a reduced chilling effect. If the thickness of the die is varied to suit the degree of heat retention, a means of controlling the progress of solidification is provided.

Fourier's Law of Thermal Conductivity explains the above approach, i.e., the quantity of heat q transferred per hr by conduction through a plane wall of A sq ft, having a given constant conductivity, k is given by the equation:

$$q = k\,A\,\frac{t_1 - t_2}{L}\ \text{in}\ \frac{\text{Btu}}{\text{h}}$$

In which L ft is the thickness of the die wall at the surfaces of which the temperatures are, respectively, t_1 and t_2, and k is the thermal conductivity of the material of the wall expressed in Btu—ft/ft 2-h. From the equation it will be seen that the larger L becomes the smaller will be q.

Other methods of increasing riser efficiency are in common use, and a brief survey of these serves to illustrate the initiative expended on this problem, all aimed at reducing remelt ratio. One common practice, illustrated in Fig. 15, is to have certain strategic risers formed inside shell core tubes which insulates them from die, therefore increasing riser efficiency and allowing for their reduction in volume.

Built-in Die Insulation

Another method is to build the insulation into the die as a permanent feature, by hollowing out the die wall directly below the riser. The hollow is then covered over with a thin steel plate fastened in position. The plate thus, partially insulated from the die by the air gap created behind it, forms the impression surface for the riser. Other methods are the provision of gas burners directly behind the die wall adjacent to the riser or of heat insulating lagging.

Conversely, to hasten solidification locally, water cooling can be used, especially where heavy sections require chilling, since they cannot be adequately fed. Water cooling is used particularly in the case of long slender cores which cannot readily be removed from the die for quenching. As a practical illustration of the application of these principles of directional solidification, the case of the casting shown in Figs. 16 and 17, made by two entirely different techniques, is quoted.

These two figures illustrate the economies which have been obtained by a careful study of the disposition of runners and risers, and the thermal aspects of the die design. Using the original method shown in Fig. 16, the fettled casting weighed 12½-lb, and the runners and risers totalled 21 lb/casting. With the same die, modified by the progressive feeding

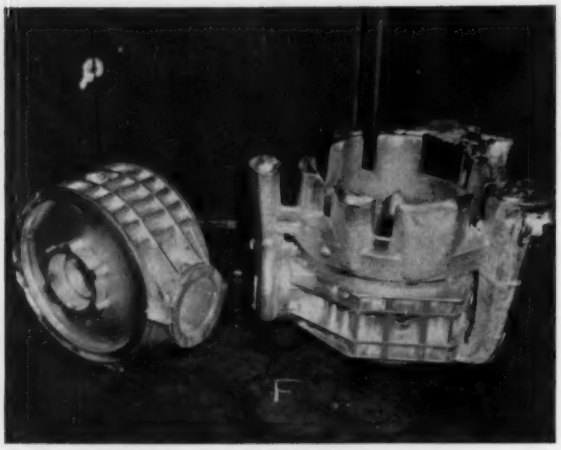


Fig. 16 — Original method of risering.

Fig. 17 — Revised method of risering.

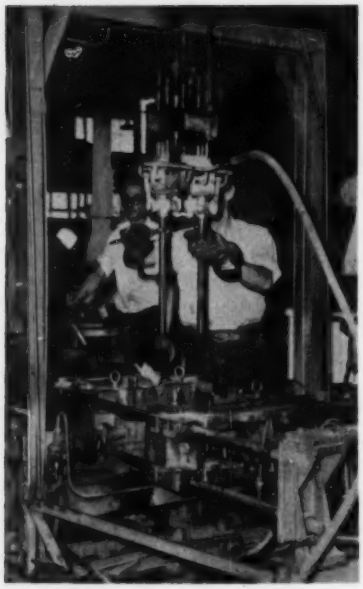


Fig. 18 — Mechanized double impression die with steel inserts.

technique (shown in Fig. 17) the total remelt weight was reduced to approximately 5 lb, by using a single riser positioned over the internal central boss. A sounder casting and a higher rate of production was obtained using the revised technique, together with a large reduction in fettling costs.

Air cooling is not as effective a means of cooling as water, and is usually employed where an overall reduction in general die temperatures is required. For example, if a given design produces satisfactory quality castings when operated fairly slowly, a speeding up of production can cause the overall die temperature to increase and poor quality may result. This increase in temperature is offset by the application of air cooling jets directed against the rear of each die block or at specified areas where cooling is required.

The mechanization of the process has facilitated the use of multi-impression dies, and of systems whereby one operator may work more than one die. Figure 18 shows a casting machine producing two castings per cycle from a two-impression die. A steel tube insert is cast in position, and the method involves the pouring of both castings simultaneously through a single runner.

Economic Use of the Solidification-Dwell Time

The only idle time that is normally available in the casting sequence, is the solidification dwell during which the die is at rest.

By the correct use of a suitable cooling medium this solidification dwell time can be kept to an absolute minimum, but during long solidification dwells it may be possible for a much smaller and simpler die to be operated alternately by the operator.

Another method is that of employing a duplex mechanized die assembly, as in Fig. 19, in which one die is open while the other is closed, and by alternate operation, time is saved.

"Shuttle-base" dies, as shown in Fig. 20, are also used, which have a sliding base which can be shuttled to and fro between one set of die blocks. Mounted on this sliding base are two separate location positions into which the sand cores or inserts can be loaded alternately during the solidification dwell.

Sand Cores

The older type of sand core formed by oil binders is fast disappearing, and is being replaced by CO_2 and shell cores. Both types can be formed by core blowing methods, which are coming into increasing use, but the majority of shell cores are still produced by the dump box method, illustrated in Fig. 21. In the latter method the sand mix, which may be a dry mix with resin or of the pre-coated type, is charged into cylinderical shaped hoppers open at one end.

This hopper is fastened on the cast iron or aluminum core box, which is trunnion mounted and maintained at a temperature of 200 C (392 F). The core box, with hopper attached, is rotated through 180 degrees filling the heated core box with sand. To complete the investment, the core box is rocked from side to side, and after a suitable time has elapsed is emptied of surplus sand by rotating back

to its original position and the shell core is removed.

The shell method produces a well defined core with a high quality surface finish and quite large cores, and fairly complicated assemblies, can be produced.

The main advantage of the shell core is its extreme lightness, and large cores can be lifted and placed into the die with ease. A comparable solid core produced by the CO_2 process would require lifting appliances.

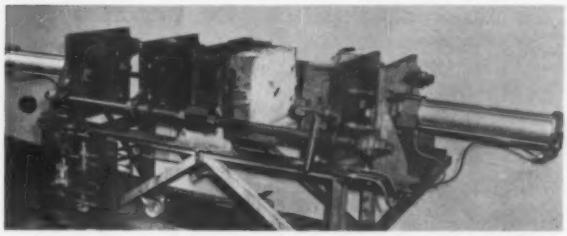


Fig. 19 — Typical twin die mechanized equipment.

The As-Cast Gravity Die Casting Alloys

Probably the most popular as-cast alloy for general use in gravity die casting is that designated LM 4M in the British Standard range of alloys B.S.1490 (Fig. 22).

This alloy has become extremely popular since World War 2, when it was developed with the aim of combining the good machinability and high proof stress of the aluminum-copper series of alloys with the good foundry characteristics and freedom from hot shortness of the aluminum-silicon series and to make the maximum use of available wrought alloy scrap.

The good machining characteristics and the retention of quite reasonable properties at moderately elevated temperatures makes the alloy suitable for such applications as motor cycle cylinder heads and for many of the manifolds, clutch housings, etc., on motor cars, and for many domestic applications.

Fig. 22 also includes the cheaper alloy, LM 21M, basically similar to LM 4M, but with larger permitted amounts of zinc impurity. Castability is inferior to LM 4M, and applications for it more restricted.

The LM 6M alloy, and the cheaper alternative LM 20M, are popular for gravity die casting, with considerable thin sections. The optimum mechanical properties are obtained by the use of a sodium modification treatment whereby the coarse crystalline structure of the as-cast alloy is converted into a fine grained structure. For best results, care must be exercised in the foundry to avoid contamination, particularly with iron and to guard against excessive gas.

Fig. 20 — Two impression die operating the "shuttle base" system.

The alloy is readily cast by the gravity process, but adequate risers must be provided to feed the solidifying metal. The alloy has a good name for pressure tightness, and this is because any slight shrinkage porosity present does not exist in a dendritic form but in the form of unconnected cavities,

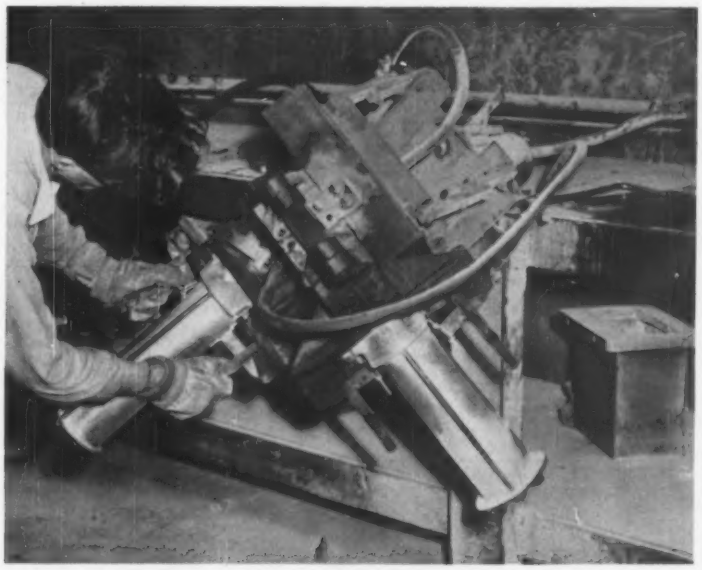


Fig. 21 — Dump box method of shell core production.

MAX. VALUES.

SPECIFICATION IDENTITY BS 1490 (AIRCRAFT)	NOMINAL COMPOSITION. %					TYPICAL TENSILE PROPERTIES OF STANDARD GRAVITY DIE CAST TEST BARS				CHARACTERISTICS.						
	Si	Cu	Mg	Mn	OTHERS	0.1% PROOF STRESS TONS SQ" PSI	TENSILE STRENGTH TONS SQ PSI	ELONG'N % ON 2" GL	BRINELL HARDNESS	CASTIBILITY	STRENGTH	SHOCK RESISTANCE	SERVICE TEMP LIMIT °C	MACHIN-ABILITY	RESISTANCE TO ATMOSPHERIC ATTACK	TYPE OF ANODIC FILM
LM4M (DTD424A)	5.0	3.0	—	0.5	Zn 0.4 #	4.5 10,000	11.0 24,500	3	75	V.GOOD	LOW	MED.	150	GOOD	FAIR	GREY
LM6M (DL 33)	11.0	0.1 #	0.1 #	—	Fe 0.6 # Zn 0.1 #	4.5 10,000	13.5 30,500	10	60	V.GOOD	MED.	HIGH	"	FAIR	GOOD	GREY
LM1M	3.0	7.0	—	—	Zn 3.0	7.0 15,700	11.0 24,500	2	80	GOOD	LOW	MED.	"	GOOD	POOR	CLEAR
LM5M (DTD 183A)	—	—	5.0	0.5	—	5.0 11,000	11.0 24,500	5	70	FAIR	MED.	HIGH	"	GOOD	V.GOOD	CLEAR
LM7M	2.25	1.5	0.1	—	Fe 1.0 Ni 0.2 1.0	6.0 13,500	11.0 24,500	2	75	GOOD	LOW	MED.	200	GOOD	FAIR	CLOUDY
LM18M	5.0	—	—	—	—	4.5 10,000	10.0 22,400	6	50	GOOD	LOW	HIGH	150	FAIR	GOOD	CLOUDY
LM20M	11.5	0.4 +	0.15 +	—	Fe 0.7 # Zn 0.2 #	4.5 10,000	14.0 31,400	7	60	GOOD	MED.	HIGH	"	FAIR	FAIR	GREY
LM21M	5.0	3.0	—	0.5	Zn 2.0 #	6.0 13,500	12.0 27,000	3	85	FAIR	MED.	MED.	"	GOOD	FAIR	CLOUDY

Fig. 22 — Aluminum alloys used for gravity die casting in as-cast condition.

the material between the individual holes being sound.

As can be seen from Fig. 22, the mechanical properties are quite attractive in spite of a fairly low 0.1 per cent proof stress value. The high ductility and good corrosion resistance proves to be an advantage for many applications.

Other Alloys

As can be seen from Figs. 10 and 22, there are several other alloys in which gravity die castings are produced. For example, alloy LM 1, although possessing rather poor properties, has extremely good machinability and good anodizing properties, readily castable and cheap.

The alloy LM 5M is particularly suited for applications where a high resistance to corrosion, including marine, is required. The alloy requires a special foundry treatment because of its fairly high magnesium content, observing similar precautions to LM 10W discussed later.

Substantial quantities of commercial gravity die castings for lightly stressed applications are also produced in the as-cast cheaper alloy, designated LM 7M, which is basically similar to R.R.50, but the intentionally wider compositional limits make it much cheaper. In this alloy the magnesium content, on which heat treatment depends, is not controlled and the alloy is, therefore, only available in the as-cast condition.

LM 18M is mainly restricted to castings for chemical plant and for food applications, but possesses low strength.

Heat Treatable Gravity Die Casting Alloys

The first alloy, LM 23P (Fig. 23) is readily castable by the gravity process and used for a wide range of engine components. The alloy can be particularly recommended for applications requiring a relatively high rigidity and moderate shock resistance.

A simple precipitation heat treatment only is needed and the alloy retains good mechanical properties up to 200 C (392 F). The ability to develop these properties without the necessity for a full solution treatment is considered an advantage for many purposes.

Alloy LM 4 is also susceptible to improvement by heat treatment, provided the magnesium and certain other impurities are controlled. If the magnesium content is restricted to the range 0.07 to 0.125 per cent attractive properties are obtained, but if the mag-

MAX. VALUES

SPECIFICATION IDENTITY BS 1490 (AIRCRAFT)	NOMINAL COMPOSITION. %					TYPICAL TENSILE PROPERTIES OF STANDARD GRAVITY DIE CAST TEST BARS.				CHARACTERISTICS.						
	Si	Cu	Mg	Mn	OTHERS	0.1% PROOF STRESS TONS SQ" PSI	TENSILE STRENGTH TONS SQ PSI	ELONG'N % ON 2" GL	BRINELL HARDNESS	CASTIBILITY	STRENGTH	SHOCK RESISTANCE	SERVICE TEMP LIMIT °C	MACHIN-ABILITY	RESISTANCE TO ATMOSPHERIC ATTACK	TYPE OF ANODIC FILM
LM23P (L.51)	2.5	1.0	0.1		Fe 1.0 Ni 1.0 Zn 0.2	8.0 18,000	13.0 29,000	3.0	75	VG	MED.	MED.	200	V.GOOD	F.GOOD	CLOUDY
LM4 WP.	5.0	3.0	0.07 0.2	0.5	Zn 0.4 #	14.65 32,800	19.75 44,200	2.3	112	V.GOOD	MOD. HIGH.	MED.	150	V.GOOD	FAIR	GREY
LM22W.	5.0	3.3	0.05 +	0.45	Zn 0.5 # Ni 0.5 # Fe 0.7 #	7.0 15,700	17.0 38,000	9.0	75	GOOD	"	HIGH	200	F.GOOD	FAIR	GREY
LM8 P (DTD 722)	5.5	—	0.5	—	—	8.0 18,000	12.5 28,000	2.0	75	V.GOOD	"	MED.	150	GOOD ESPECIALLY 'W P'	V.G TO EXCELLENT	CLOUDY
W (DTD 727)	5.5	—	0.5	—	—	6.5 14,500	15.0 33,400	5.0	65							
LM 8. WP (DTD 735)	5.5	—	0.5	—	—	14.0 31,400	18.0 40,000	2.0	90	V.GOOD	"	MED.	"	"	"	"
LM9 P (DTD 1240)	11.5	—	0.4	0.5	—	8.5 18,000	16.0 36,000	2.5	80	V.GOOD	"	MED.	"	FAIR	"	"
WP (DTD 945A)	11.5	—	0.4	0.5	—	17.0 38,000	20.0 44,800	1.0	110							
LM10.W. (L.53)	—	—	10.5	—	—	11.0 24,500	21.0 47,000	17.0	90	FAIR SPEC TECH.	VERY HIGH	GOOD	R.T.	GOOD	V.GOOD	CLEAR
LM12 WP	—	9.75	0.25	—	Fe 1.0	18.0 40,000	20.0 44,800	—	130	F.GOOD	HIGH	F.GOOD	PISTON USAGE.	V.GOOD	POOR	CLEAR
LM13.WP	12.0	0.9	1.2	—	Ni 2.5	17.0 38,000	19.0 42,000	—	12.5	GOOD	HIGH	F.GOOD	"	FAIR	GOOD	GREY
LM14. (DL 35)	—	4.2	1.5	—	Ni 2.0	15.0 33,400	19.0 42,000	2	110	FAIR	MOD. HIGH	V.LOW	300	V.GOOD	FAIR	CLOUDY
LM15 (L.52)	0.75	1.5	0.8	—	Fe 1.0 Ni 1.0 Zn 0.2	21.0 47,000	23.0 51500	2	140	FAIR	HIGH	LOW	UP TO 300	V.GOOD	FAIR	CLOUDY
LM.16. (DTD 272A)	5.0	1.25	0.5	—	—	10.0 22,000	15.0 33,400	6	85	GOOD	MOD.	F.GOOD	150	GOOD	GOOD	CLOUDY
LM16. WP (DTD 276A)	5.0	1.25	0.5	—	—	16.0 36,000	19.0 42,000	2	110	GOOD	HIGH	FAIR	150	GOOD	GOOD	CLOUDY

Fig. 23 — Aluminum alloys used for gravity die castings in heat treated condition.

nesium is allowed to fall below this range proofstress tensile strength and Brinell hardness fall off but percentage elongation improves.

If the magnesium is controlled in the range 0.2-0.3 per cent, high hardness values of 130 are possible with a high proof and tensile strength, and a percentage elongation is adequate for most purposes.

Alloy LM 22M, also in this group, takes advantage of the fact that when the magnesium impurity is not higher than 0.05 per cent, and the other impurities are kept low by good foundry control, the alloy can be solution treated to give attractive properties remaining stable. The typical 16 tons/sq in. tensile strength and 8 per cent elongation from chill cast test bars is attractive despite the rather low 0.1 per cent proofstress and Brinell hardness. Castability is good, however, and the alloy is often preferred to the high strength LM 10W or LM 11WP types, both of which exhibit foundry difficulties.

Other Heat Treatable Alloys

Two further alloys which are popular and capable of producing attractive mechanical properties by the process of heat treatment, are LM8P, W and WP and LM 9P and WP. They are heat treatable by virtue of the presence of magnesium or magnesium silicide, and careful control of this element is necessary. Being readily cast by the gravity die casting process with no tendency to hot shortness cracking, these alloys have particularly good corrosion resistance, and also have good machinability in the fully heat treated condition.

The LM 9 alloy unlike the alloy LM 8, by reason of its higher silicon content, normally requires sodium modification. For higher strengths and better ductility the LM 10W type alloy, which contains basically about 10 per cent of magnesium, and which is dependent for its high tensile properties on a solution treatment, must be used. A special foundry technique much more akin to that practiced for magnesium than for aluminum alloys must be used for the alloy.

The molten alloy anodizes rapidly if the surface is unprotected, and gas pickup is greatly increased. The alloy has a long freezing range and in the design of dies changes of section must be gradual to avoid shrinkage cracks and draws. Good tapers must be provided and heavier section must be well risered. The alloy takes longer to solidify than other alloys, and removal from the die must be delayed until the castings are completely solid. The iron and silicon impurities must be maintained at a low level, and control must ensure retention of the correct magnesium content.

The four alloys, LM 12, 13, 14 and 15, which are popularly used for cast piston manufacture must be mentioned; of these probably the most popular is LM 13WP. This alloy does not have quite as good mechanical properties at elevated temperature as LM 14WP, but it preserves good wear resistance and low coefficient of thermal expansion and good machinability make it especially suitable for piston manufacture.

The LM 14WP alloy is used for pistons in high performance engines. Similar purposes are performed by the other two alloys, LM 12 and LM 15, but these are not as popular as the former two. Alloy LM 16WP finds considerable usage producing attractive mechanical properties, but not possessing such good corrosion resistance.

MODERN METHODS OF METALLURGICAL AND FOUNDRY CONTROL

For reasons of economics, the degree of control will vary according to the process, alloy and end use of the casting concerned.

Chemical Composition

In the pressure die foundry, the main objects are to ensure conformity with compositional limits which, with the normal copper-containing aluminum-silicon alloys, are normally quite wide, and to ensure that the metal is free from serious impurity, hard spot inclusion or undesirable segregation effects. With gravity die casting, due to the wider range of alloys cast and to the end use, including often important aircraft usage, the degree of metallurgical control can at times be of necessity stringent.

Basic alloy development on the alloys used for pressure die casting has been somewhat limited perhaps, with the exception of the newer pressure die casting alloy LM 24M. By the normal process of evolving the specifications, however, compositional limits are established which are wide enough to enable secondary materials to be abundantly used, but not wide enough to allow the characteristics or properties of the alloy to be seriously altered by variations in composition within those limits.

It is the view that composition should be checked, and steps taken to ensure that all material falls within these required limits. The properties of nonspecification alloys can always be regarded with suspicion, and their use has had undesirable effects.

The practice of all reputable die casters in Britain is to adhere to these standards, and one way in which this is achieved is for an individual company to set its own internal limits slightly tighter than the national specification. Slight accidental variation outside the firm's internal limits therefore may not bring material outside national limits.

The older wet chemical methods of analysis are far too slow to ensure effective control nowadays.

Spectrographic Technique

Full advantage has been taken of the direct reading spectrograph techniques which became available, and using this type of equipment, which is far less expensive than the full quantometer, has enabled a full coverage to be made well within 24 hr. This introduction of direct reading methods meant that all cast material could be checked before any of it had received any after treatment. Waste, due to processing material compositionally unsuitable, is, therefore, eliminated.

Other than giving the required speeding up of the analysis process itself, the improved technique has

several other beneficial effects. For example, the cost of individual analysis is greatly reduced by the fact that photographic plate is no longer required. The number of individual determinations which an operator can perform in a single shifts working is greatly increased. Melts outside specification has been reduced to practically nil, and the general composition ranges of most of the alloys have been appreciably narrowed because of better compositional control.

The normal procedure in melt control is to watch the trend of end product analysis. If this is showing a drift in impurity levels towards the maximum, it will be "sweetened" by the use of an increased amount of purer ingot until the trend has been arrested, or vice versa.

This procedure has enabled difficult elements in certain alloys to be rigidly controlled when required. Using this method, for example, it has been possible to control magnesium contents to within close limits.

Tensile Tests

The second method of controlling the metallurgical quality of the product is by the testing of separately cast test bars by the tensile test, plus on occasions a Brinell hardness test. Minimum values for tensile properties have been derived in the evolution of the specification, and the test is normally critical enough to pick up any adverse metallurgical effects.

The presence of adequate alloying constituent and the presence of excessive amounts of harmful impurities, the presence of detrimental nonmetallic impurities, a measure of the gas content of the metal and whether heat treatment has been carried out satisfactorily can be determined.

The procedure requires the casting of three individually cast test bars of standard B.S. type to produce a single 1 in. diameter cast bar approximately 7 in. long from which the test piece itself is machined. The test pieces are given the same complete thermal cycle that the castings receive prior to test.

With the pressure die casting process, it is particularly important to check against the existence of hard spot inclusions which can form and give machining troubles, especially in the case of castings which are subjected to a certain amount of drilling or machining. There are several forms which these inclusions take, but they mostly contain hard aluminum oxide.

If molten LM 2 alloy is left standing for long periods at low temperature without disturbance, there is a tendency for iron and manganese constituents to settle out forming heavy sludges.

Casting Practice Control

To ensure the establishment of a satisfactory and economic casting technique, it is necessary to institute both a "first off" checking and approved routine check.

Production methods can sometimes drift gradually away from the ideal, unless such a routine is carried out covering all aspects of casting quality, metallurgical as well as dimensional, etc.

The normal technique when such a casting check is made is to produce a number of samples from the new die. In the case of pressure die castings, the die is normally given a short run in the unhardened state. This will provide samples for dimensional checking and approval by the customer. The surface finish and internal soundness cannot, however, be fully assessed at this stage, but certainly such preliminary checks are of great value.

It is considered to be a precaution worth taking at this stage to subject one or two castings to radiographical examination, so that their internal quality can be fully assessed. The information yielded by this type of examination can often be of great value in altering some feature of the runners, etc., which leads to improved casting quality and less overall scrap.

A new die, whether gravity or pressure, will often be operated initially by one of the more skilled operatives, or by the shop foreman until castings of a fully acceptable standard are produced. It is also considered worth while to make a card record of the optimum conditions once these have been established, and to refer to this each time that die is put into use.

Occasionally, as and when circumstances require, important castings may need to be subjected to a much more thorough cut up test and metallurgical examination to fully assess their quality and suitability for specific applications.

The demand for both gravity and pressure die castings is growing rapidly, as is the ever increasing need for castings of greater complexity, higher and higher quality standards and even greater reliability. Nothing is more certain than that this industry will in the future never rest until such demands are fully satisfied.

FUTURE TRENDS FOR DEVELOPMENT

With these ends in view it is considered to be certain that the coming years will see developments taking place even more rapidly than in the past to produce the improvements in casting quality and economics. To this end it is anticipated that the application of vacuum to the die in pressure die casting, which we read so much about in the American technical press, will become adopted into British practice. This may greatly improve general levels of quality, and do much to remove or at least minimize the limitations still existing today.

There is a current trend also toward the use of bigger pressure die casting machines for producing the large castings which will be the requirement of the future. A high degree of mechanizations of all handling equipment must of necessity follow.

In the same way we anticipate the adoption of more and more mechanization of the gravity process, and the general adoption of the principle of autoladling which seems likely to become regular practice.

ACKNOWLEDGMENT

The authors wish to express our appreciation to the Directors of High Duty Alloys, Ltd., for permission to use material included herein, and to their many colleagues for their help in the preparation of this Paper.

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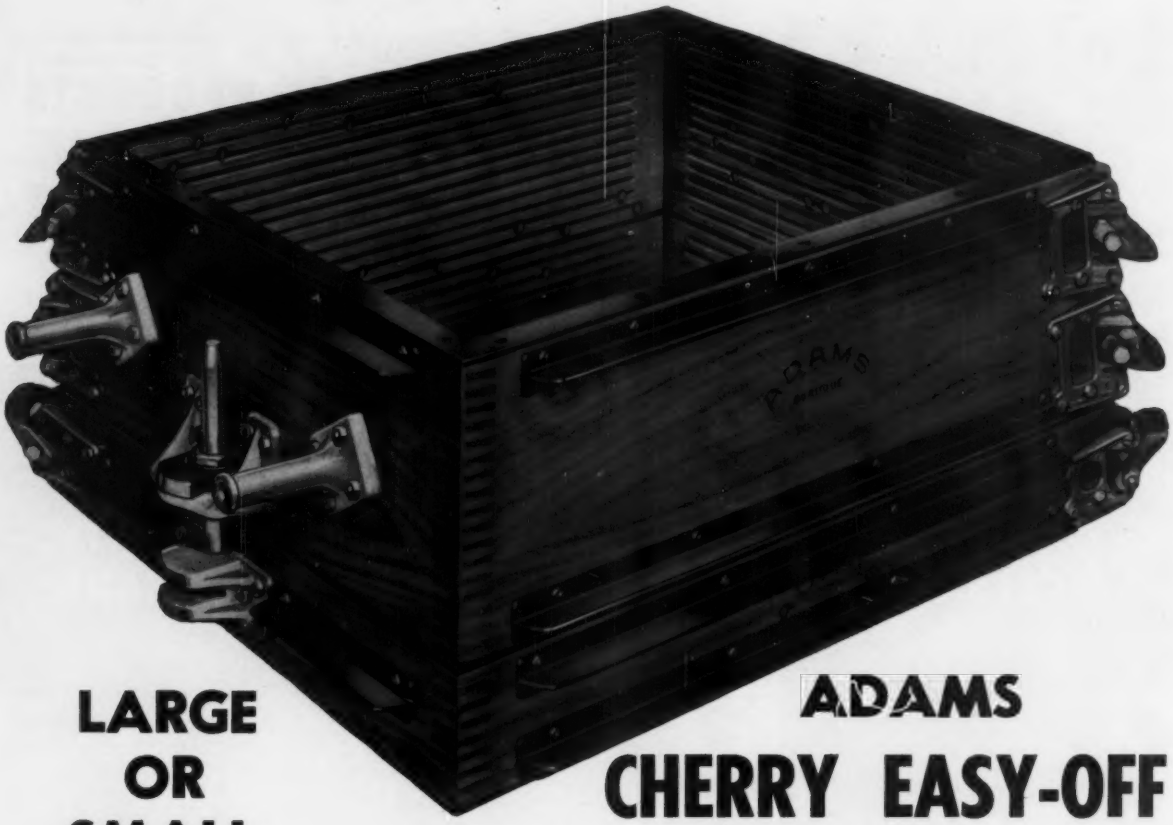

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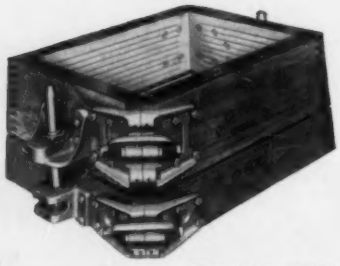

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65th CASTINGS CONGRESS

AFS CONVENTION NEWS

SUPPLIES & EQUIPMENT EXPOSITION

SAN FRANCISCO, MAY 8-12, 1961

Convention Emphasizes Latest in Technology and Research

Innovations in more than equipment and techniques will be evident at the AFS 1961 Castings Congress & Exposition. San Francisco will be host—the first time for the far west. The booming economy of the western states was one of the reasons for the selection of San Francisco.

Within the Exposition itself, several new looks are being added. One will be the identification of the aisles. Familiar streets in major foundry centers will replace the standard numbers.

Exhibitors will be telling their customers to meet them at 641 Market St., 104 Woodward Ave., or the corner of Hennepin and Bessemer. Other aisles will be named for Broadway, Main St., Pennsylvania Ave., State St., Broad St., and Lindell Blvd.

AFS Headquarters will be located at Golf and Wolf Roads—but 2200 miles from DesPlaines, Ill.

Demonstration areas for mobile equipment will be another first. This space will provide sufficient room for such equipment as fork lift trucks, front-end loaders, and other materials handling machinery.

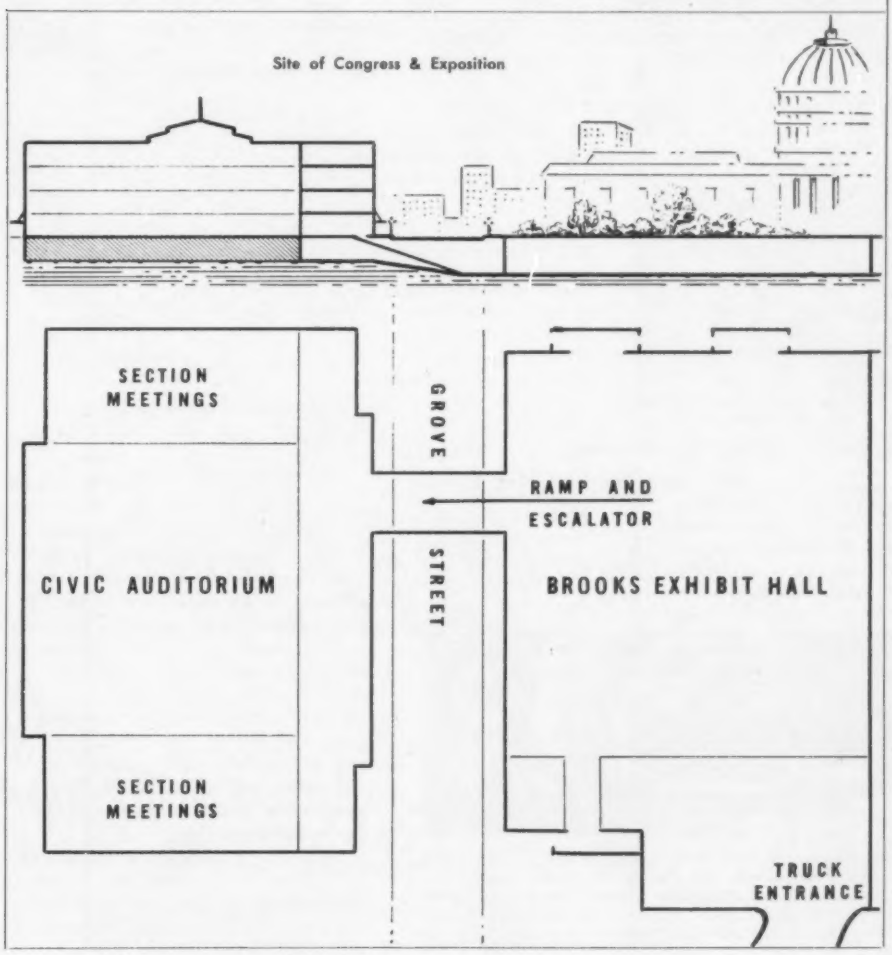
Survey Indicates A Big Market

Nearly 70 per cent of foundries expect to buy new equipment during the next year. This, according to a recent survey, emphasizes our industry's interest in and need for modernization and mechanization. It further points up the importance of the 1961 Exposition in San Francisco.

This event will be the only industry-wide display of foundry equipment and supplies during the next year.

The survey further indicates that nearly 72 per cent of the foundries in the U. S. will invest in molding equipment and 59 per cent in materials handling machinery.

Other equipment classifications and their indicated percentages are: cleaning, 53 per cent; melting, 39 per cent; laboratory, 35 per cent; and inspection, 23 per cent.



Brooks Hall and the Civic Auditorium provide exceptional convenience. Technical sessions will be held in the Auditorium and the Exposition in the adjoining, underground Brooks Hall.

Hear Top Papers at 65th Congress

Nearly 100 authoritative technical papers on all phases of foundry research are to be presented at the 65th Castings Congress.

The tentative technical program:

MONDAY—Brass & Bronze; Malleable; Pattern; joint Gray, Ductile and Malleable luncheon; Heat Transfer; Sand; Safety, Hygiene & Air Pollution; Sand shop course; and Pattern shop course.

TUESDAY – Light Metals, Brass & Bronze, Pattern, Malleable, Brass and Bronze and Pattern luncheons, Industrial Engineering & Cost, Gray Iron, Sand, Education, Gray Iron, Gray Iron shop course, Sand shop course.

WEDNESDAY – Management luncheon, Light Metals luncheon, Steel, Gray Iron, Plant & Plant Equipment, Industrial Engineering & Cost, Die Casting & Permanent Mold, Sand, Steel.

THURSDAY—Steel, Ductile Iron, Fundamental Papers, Die Casting & Permanent Mold, Steel and Die Casting luncheons, Fundamental Papers, Sand, Steel, Gray Iron, Die Casting & Permanent Mold, ductile Iron, Gray Iron shop course, Ductile Iron shop course.

FRIDAY – Sand, Ductile Iron, Fundamental Papers.

NEWS and VIEWS

Programs for Regional Conferences
AFS Revises Patternmakers Manual
Assign Chapter Contacts to Directors

Annual AFS Apprentice Contest Offers Cash Prizes; National Recognition to Industry Beginners

The AFS Robert E. Kennedy Memorial Apprentice Contest for 1961, carrying a starting date of Oct. 1, offers nation-wide competition for foundry beginners. Cash awards and industry recognition await winners in the national contest. All entries for national judging must be submitted by March 31, 1961.

AFS Education Director R. E. Betterley urges an early start for all plants and local chapters intending to participate.

The first step is to furnish AFS Headquarters with the name of one person to act as the official contact. He will receive all correspondence concerning the contest as well as materials and instructions. Prior to the actual receipt of entries for judging, all contest activities and correspondence should be addressed only to the AFS Education Director, Golf & Wolf Roads, Des Plaines, Ill.

At the time that patterns or blueprints are requested for local contests, the AFS Headquarters must be furnished with the full names, companies, and respective divisions of all intended contestants. The official numbered identification tags for contestants cannot be provided until such information is received. All entry numbers are identified only at AFS Headquarters.

Competition will be held in five divisions; wood patternmaking, metal patternmaking; iron molding, steel molding, and non-ferrous molding.

The amount of training has no bearing on eligibility and is not considered in the judging.

Prizes and Awards

Cash prizes of $100 for 1st place, $75 for 2d place, and $50 for 3d place will be awarded to the winners in each of the five divisions. Certificates of recognition will be presented to all winners in each of the divisions.

In addition, each first place winner in each contest division will be invited to attend the 1961 AFS Castings Congress & Exposition in San Francisco, May 8-12. He will receive his award in person. The winner will have his round-trip travel expense paid by the Society to and from San Francisco. All other expenses shall be assumed by the winner, his company, or his local chapter.

Judging

Judging of national entries shall be conducted on a point score determined by the Apprentice Contest Committee of the Education Division, sponsor of the contest. The following 100-point system will be used:

Wood Patternmaking

Accuracy according to drawing	35 max.
Moldability	35 max.
Workmanship	20 max.
Time	10 max.

Metal Patternmaking

Accuracy according to drawing	50 max.
Workmanship	30 max.
Time	20 max.

Molding Divisions

Gates and risers	20 max.
Yield	10 max.
Cleanability	10 max.
General appearance	20 max.
Soundness	25 max.
Time	15 max.

Local Contests

Local contests may be held under auspices of AFS chapters or by individual plants acting separately or in a group, to determine which castings and patterns shall be entered in the national contest. The 1961 contest rules and regulations shall apply for all local contests. Committees to conduct local contests shall be appointed by sponsoring chapters or plants.

Plans for the 1961 Convention were discussed by the Pattern Division Program & Papers Committee at an August meeting, AFS Headquarters, Des Plaines, Ill. Seated around the table are R. L. Olson, Dike-O-Seal, Inc., Chicago; J. M. Kreiner, National Malleable & Steel Castings Co., Cleveland; L. H. Kinney, Chrysler Corp., Detroit; R. A. LeMaster, Nelson Pattern Co., Milwaukee; M. K. Young, U. S. Gypsum Co., Chicago; and AFS Technical Director S. C. Massari.

Mexico to Conduct Foundry Convention

Mexico's first national convention of the foundry industry will be held Nov. 21-23 in Mexico City.

The convention has a four-point goal: 1) to stimulate the future development of the foundry industry; 2) to bring the industry's progress to the general public; 3) to increase the exchange of technical knowledge between foundrymen; and 4) to promote better contact between producers, suppliers, and casting customers.

Papers have been solicited on gray and white iron, malleable and ductile, steel, and non-ferrous castings. Other subjects include quality control, molding sands, raw material supply, and the present and future of castings in the national market.

Sponsors of the convention are the AFS Mexico Chapter, the National Chamber of the Iron and Steel Industry, and the National Chamber of Transformation Industry.

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10-A-3

How to Sell Aircraft Castings Stressed at Michigan Meeting

New foundry techniques to cut costs and improve quality will be emphasized at the Michigan Regional Conference. The two-day conference will be held Nov. 3-4 at the Bancroft Hotel, Saginaw, Mich.

The conference is sponsored by the AFS Saginaw Valley, Central Michigan, Detroit, and Western Michigan Chapters. Vernon Sadler, General Foundry & Mfg. Co., Flint, Mich., is the general conference chairman. Jerome Young, Cadillac Motor Car Div., General Motors Corp., Detroit, is program chairman.

Technical sessions will be supplemented by a plant visitation tour on the final day.

THURSDAY, Nov. 3

9:45 am "Permanent Molding," by representative of Ford Motor Co., Dearborn, Mich.
9:45 am "Magnesium Die Casting," Steven L. Strong, A. C. Spark Plug Div., General Motors Corp., Flint, Mich.
11:00 am "Ductile Iron," W. D. McMillan, Ohio Ferro-Alloys Corp., Chicago, Ill.
Noon Luncheon talk, "What to do if Your Foundry Catches Fire," D. N. Duncanson, Western Adjustment & Inspection Co., Detroit.
1:30 pm "Furfural Cores," representative from Pontiac Motor Car Div., Pontiac, Mich.
2:30 pm "Should You Consider an Automated Sand System?", Randolph Dietert, Harry W. Dietert Co., Detroit.
3:30 pm "How to Set Up a New Foundry," J. W. Nuss, American Radiator & Standard Sanitary Corp., Louisville, Ky., and Eric Welander, John Deere Malleable Works, East Moline, Ill.
6:00 pm Banquet speaker, William Sheehan, Radio Station WJR, Detroit.

FRIDAY, Nov. 4

8:30 am "How to Sell Castings to the Aircraft Industry," Harry Gravlin, Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn.
9:45 am "Shell and CO_2 Processes," speaker to be announced.
9:45 am "Casting Design," John L. Flitz, Central Foundry Div., General Motors Corp., Saginaw, Mich.
10:45 am "Group Discussions," Nicholas Sheptak, Dow Metal Products Co., Midland, Mich.
10:45 am "Student Session," R. E. Betterley, AFS Education Director.
Noon Luncheon speaker to be announced.
1:00 pm Plant visitations to Saginaw Malleable Iron Plant, Central Foundry Div., General Motors Corp., Saginaw, Mich.; Chevrolet-Saginaw Grey Iron Div., General Motors Corp., Saginaw, Mich.; Dow Chemical Co., Midland, Mich.

British Columbia Hosts Northwest Conference

Nine speakers will address foundrymen attending the 11th annual Northwestern Regional Foundry Conference which will be held Oct. 21-22 at the Hotel Georgia, Vancouver, British Columbia. Plant visitations will be conducted Friday afternoon, Oct. 21.

Friday morning's program will include a talk for iron foundrymen by G. I. Pound, Dominion Bridge Co., Ltd.; a light metals subject by Paul Hookings, Granby Consolidated; and a pattern paper by W. Wenninga, Park-Hannesson, Ltd.

Friday evening, W. B. Johnson, Aluminum Co. of Canada, will speak on "The Wonderful World."

Three papers will be given Saturday morning: "Pipe Manufacturing," G. Harris, Anthes Imperial Co., Ltd.; "Cast Iron Melting Furnaces in Canada and Future Trends," F. W. Kellam, Ferro Alloys & Electrodes Div., Union Carbide Canada, Ltd.; and "Steel Melting in Hawaiian Plant," J. R. Belyea, Vancouver Steel Co., Ltd.

In the afternoon W. C. Catherall, Vancouver Technical School, will outline "Educating our Future Foundry Personnel," and J. Provias, International Nickel Co., Ltd., will discuss "Ductile Iron."

Purdue Meeting Set for Oct. 27-28

General meetings and concurrent sessions for specific interests form the program for the Purdue Metals Casting Conference to be held Oct. 27-28 at Purdue University, Lafayette, Ind. Simultaneous sessions will be held both Thursday morning and afternoon.

The conference is sponsored by the AFS Central Indiana and Michiana Chapters, the Purdue University Student Chapter, and Purdue University.

Howard Vorhees, manufacturers' agent, Mishawaka, Ind., is the conference general chairman. T. E. Smith, Central Foundry Div., General Motors Corp., Danville, Ill., is program chairman.

Conference Chairman Vorhees will preside at the opening sessions and Program Chairman Smith will be master of ceremonies at the dinner.

Dr. George E. Davis, Purdue University, will be the banquet speaker at 6:30 Thursday evening in Purdue Memorial Hall. His subject will be, "Hoosier Philosophy."

THURSDAY, Oct. 27

9:00 am Registration, Purdue Memorial Center.
10:00 am Welcome, John W. Hicks, assistant to the president, Purdue University. Response, AFS Regional Vice-President D. W. Boyd, Engineering Castings, Inc., Marshall, Mich.
10:45 am "Solidification of Metals," R. W. Ruddle, Foundry Service Co., Cleveland.
1:30 pm **Non-Ferrous Session**—"Melting of Copper-Base Alloys," Roy Cochran, R. Lavin & Sons, Chicago.
1:30 pm **Iron Session**—"Cupola Control and Practice," Robert Greenlee, Auto Specialties Mfg. Co., St. Joseph, Mich.
1:30 pm **Steel Session**—"Manufacture of Leaded Steel Castings – Equipment, Safety, Production Features," George P. Dahm, Linde Co., Cincinnati; Herbert J. Weber, AFS Director of Safety, Hygiene, and Air Pollution Control Program; and Russell Plum, Keokuk Steel Castings Co., Keokuk, Iowa.
3:00 pm **Non-Ferrous Session**—"Gating and Risering of Non-Ferrous Alloys," Robert A. Colton, American Smelting & Refining Co., Houston, Texas.
3:00 pm **Iron Session**—"Relation of Microstructure to the Mechanical Properties of Gray Iron," S. C. Massari, AFS Technical Director.
3:00 pm **Steel Session**—"Relation of Practical Stress Patterns to the Operating Foreman's Job," John Leath, Harrison Steel Casting Co., Attica, Ind.
6:30 pm Dinner, Purdue Memorial Union. "Hoosier Philosophy," Dr. George E. Davis, Purdue University.

FRIDAY, Oct. 28

9:00 am "Quality Control," Harry Kindle, Cummins Engine Co., Columbus, Ind.
10:15 am "Adaptability and Economics of the Shell Core Process," M. H. Horton, Deere & Co., Moline, Ill.
11:30 am **Preventive Maintenance.** Panelists: Glen Snellenberger, Dalton Foundry Co., Warsaw, Ind.; Paul Simmonds, International Harvester Co., Indianapolis; Robert Clark, Golden Foundry Co., Columbus, Ind.

BOARD OF DIRECTORS—and AFS Staff members met lately in Chicago to outline future plans and policy. Seated clockwise are W. H. Oliver, A. E. Falk, D. W. Boyd, D. E. Webster, C. A. Sanders, H. M. Patton, W. L. Kammerer, R. E. Mittlestead, AFS Vice-President A. L. Hunt, AFS President N. J. Dunbeck, Jake Dee, W. C. Jeffrey, J. T. Moore, C. E. Nelson, A. J. Moore, T. T. Lloyd, W. E. Sicha, N. N. Amrhein, and D. L. Colwell. Standing: Technical Director S. C. Massari, D. E. Matthieu, Secretary A. B. Sinnett, General Manager W. W. Maloney, and Treasurer E. R. May. The board reviewed the Society's goals and plans for the coming year.

Canadian Conference Features Technical Talks, Plant Visits

Sand, iron, steel, and non-ferrous sessions will be conducted at the All-Canadian Regional Oct. 27-28. The regional will be held at the Mt. Royal Hotel, Montreal, Quebec.

It is sponsored by the Eastern Canada and Ontario AFS Chapters. Max Reading, Foundry Services (Canada) Ltd., is chairman. Co-chairmen are A. K. Durrell, Dominion Engineering Works, Ltd.; W. Tibbits, Canadian Steel Foundries, Ltd.; and M. Trottier, Quebec Iron & Titanium Corp.

Sand sessions include: "Logic in Foundry Sands," George J. Vingas, Magnet Cove Barium Corp.; Victor Rowell, Federal Foundry Services Div., Archer-Daniels-Midland Co., subject to be announced; "Mold and Core Washes," A. E. Murton, Dept. of Mines & Technical Surveys; "The Scab Test Block Casting in Sand Control," George Greiner, Canadian Steel Foundries, Ltd.; "The Determination of True Clay and its Influence on the Quality of Molding Sand," Desmond R. Phillips, Dominion Engineering Works, Ltd.; and "Benefits of Slurry in Foundry Sands," T. V. Linabury, Miller & Co.

Iron sessions: "Self-Service Mixing Ladle at Cupola, Andre Cecil, Warden King Div., Crane Piping, Ltd.; J. E. Rehder, Canada Iron Foundries, Ltd., subject to be announced; "Cast Iron Melting Furnaces in Canada and Future Trends," F. W. Kellam, Ferro Alloys and Electrodes Div., Electro Metallurgical Co.; "Some Controls, Some Properties, Some Production Techniques of Ductile Cast Irons," P. J. Provias, International Nickel Co. of Canada, Ltd.

Steel sessions: "Welding as Applied to Foundries," C. R. Whittemore, Deloro Smelting & Refining Co., Ltd.; "Construction Problems of Large Pattern Equipment," A. E. Wells, Dominion Engineering Works, Ltd.; "Direct-Arc Steel Melting in the Foundry," Gerald Tracey and M. Colman, Canadian Steel Foundries, Ltd.; "Foundry Welding and the Electrode Influence," C. Sebistianowich, Dominion Engineering Works, Ltd.

Non-Ferrous sessions: "Selection and Application of Copper-Base Alloys in Industry," J. G. Dick, Canadian Bronze Co., Ltd.; "Some Casting Defects—Their Causes and Cures," D. A. Dobson, Foundry Services (Canada) Ltd.; "Some Recent Developments in the Metallurgy of Aluminum Foundry Alloys," V. J. Zabek, Aluminum Co. of Canada, Ltd.

Six foundries will be open for plant visitations. These include Canadian Steel Foundries, Ltd., Canadian Steel Wheel, Ltd., Dominion Engineering Works, Ltd., Montreal Bronze, Ltd., and Warden King, Ltd.

AFS Publishes New Pattern Manual

Fundamentals of patternmaking, essential to apprentices and trained mechanics, have been compiled in the AFS PATTERNMAKER'S MANUAL, 2d edition, just published by the Pattern Manual Committee of the AFS Pattern Division.

It contains over 400 pages, 342 illustrations, and 24 chapters. Ten new chapters have been added since the first edition in 1953. These include use of machine tools in wood and metal patternmaking, metal core box equipment, sealing core boxes and 36 pages of shrink tables for wood and metal patterns. The price to members is $6.50; non-members $9.50.

The opening chapter on safety, outlines hazards and safety practices. This is followed by sections on selecting wood, equipment, materials and supplies, terminology, and layout aids.

One chapter is devoted to descriptive projects, stressing the use of hand tools. Eighteen pages are used to describe wood pattern construction including building of cylindrical patterns, use of cores in pattern, use of templates in molding, segment construction, and mock-up.

Chapters on tooth gearing patterns, propeller patterns, epoxy resin plastic patterns, and patternmaking with plaster and gypsum cement are also included.

Core blowing equipment is described including fundamental requirements, designing the box, and equipment description.

An important addition is a section on the manufacture of engineered castings, discussing the casting process, shrinkage, and design. The general information chapter deals with symbols and their uses, specific gravities of materials, and decimal equivalents of circles and spheres.

Other chapters deal with pattern storage, centrifugal casting patterns, use of machine tools in patternmaking, metal core box equipment, and sealing core boxes.

The projects or jobs contained in this section are presented in a progressive manner. Their sequence depends upon the difficulty of making patterns and molding processes involved.

AFS Training & Research Course Preview

Sand Testing **Oct. 10-14**
A working course involving demonstrations and laboratory work. Students perform sand tests and are checked by instructor. Basic tests and equipment are demonstrated with emphasis on correct procedures, sand properties, variables, and controls. Recommended for sand technicians, foremen, supervisors, trainees, and sales engineers. Class limited to 25. **Place: Detroit—$150.—Course No. 13**

Foundry Plant Layout **Oct. 24-26**
Instructive course on problems of remodeling or building of new plants. Materials handling equipment, shop routing, storage, cleaning, shipment of castings, safety and hygiene, and plant location are studied. Differences of job shops and production shops are also discussed. For foreman, managers, supervisors, plant and industrial engineers, and management. **Place: Chicago—Fee: $60.—Course No. 14**

Metallurgy of Light and Copper-Base Alloys . . Nov. 7-9
A study of the basic metallurgy of these materials. Melting practices and behavior of the widely used alloys are discussed. Emphasis is placed on typical microstructures, analyses, and interpretations in light of variations in controls for improved mechanical properties. Useful to metallurgists, foundry engineers, foremen, supervisors, sales engineers. **Place: Chicago—$60—Course No. 15**

Sand Control and Technology . . . . . Dec. 5-7
Instruction course for foundrymen having some experience in sand testing, control, and technology. Mold wall movement, hot deformation, creep deformation, mold atmosphere, heat transfer, mechanical properties, and metal penetration are discussed. Students encouraged to bring problems to class for discussion. Prerequisite: Course No. 13 or equivalent. **Place: Detroit—Course No. 16**

Inclusion Study Uses New Method

Use of mercury in the investigation of non-metallic inclusions in steel castings, coming from sand erosion, will be started by the Physical Properties of Steel Foundry Sands at Elevated Temperatures Committee.

Committee member Jack Caine, consultant, Cincinnati, outlined the work he is doing with mercury poured through small unwashed sand sprues. The committee agreed to start in the preliminary phase with pouring steel through small gate cores with the erosion determined by the weight difference. Further investigation will involve the use of radioactive tracers.

The committee conducted a meeting at L.F.M. Mfg. Co., Atchison, Kans. A summary of progress was made covering research during the past two years at L.F.M. About 50 per cent of the non-metallic inclusions observed and checked under the microscope were metal-refractory reaction products and contained no sand.

It was decided that this investigation was leading away from the committee purpose and that sufficient work was being done on this phase of inclusions by others in AFS. It was agreed that the committee would concentrate on non-metallic inclusions in steel castings coming from sand erosion only.

No further use of the AFS-owned equipment is planned at the Kansas location. It will be returned to the national headquarters.

Arthur Zrimsek, Magnet Cove Barium Corp., Arlington Heights, Ill., was elected as committee chairman and J. B. Caine as vice-chairman.

T&RI Course Outlines Core Practice Data

Core practices, ranging from basic principles to the latest technology, were outlined recently in an AFS Training & Research Institute course in Chicago.

The concentrated course was designed for foremen, sales engineers, supervisors, technicians and management. All aspects of materials, mixing, sand testing, application, advantages and limitations of new products were studied. Another important subject was the analyzing of casting losses attributed to cores. Instructors made recommendations on actual foundry problems brought by student-foundrymen.

Industry leaders provided authoritative information on cores and various binders. Instructors who donated their time and their subjects included:

T. W. Seaton, American Silica Sand Co., Ottawa, Ill., core sand.

Wayne Buell, Aristo Corp., Detroit, drying type oil binders.

John Albanese, Acme Resin Corp., Forest Park, Ill., synthetic resins, core binders and shell cores.

James E. Huss, Lauhoff Grain Co., Danville, Ill., cereal binders, special binders, and core coatings.

Robert J. Mulligan, Archer-Daniels-Midland Co., Minneapolis, sodium silicate binders.

O. Jay Myers, Foundry Products Div., Reichhold Chemicals, Inc., White Plains, N.Y., semi-self curing binders.

Victor Rowell, Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland, core practices and new techniques.

Harry W. Dietert, H. W. Dietert Co., Detroit, properties of green, baked and hot cores and casting losses.

Joseph A. Gitzen, Delta Oil Products Co., Milwaukee, special binders and core coatings.

T&RI Training Supervisor R. E. Betterley conducted an achievement test.

Wheland Co. employees relax during Cupola Melting of Iron course with AFS-T&RI personnel. Course, co-sponsored by the Tennessee Chapter and the Training & Research Institute, was held recently at Chattanooga, Tenn. Left to right: Frank J. Seevers; T&RI Director S. C. Massari; E. E. Templeton; AFS Training Director R. E. Betterley; and J. N. Weir.

Modern Casting Increases Staff

D. A. Glenn

Four recent additions to the MODERN CASTINGS magazine staff are announced by Harold E. Green, managing director.

David A. Glenn, with more than 15 years in business magazine editing and production, becomes managing editor.

An alumnus of Grove City (Pa.) College, Glenn entered the Medill School of Journalism, Northwestern University, following a tour of duty in World War II.

After the war he joined *American Restaurant* magazine, later becoming managing editor. Other posts of similar and greater responsibility include *Modern Railroads* and *Appliance Manufacturer* with the Watson Publishing Co., *Meat*, and *Industrial Laboratories* and *Industrial Science and Engineering* with the Industrial Laboratories Publishing Co.

Wallace R. Fingal, well-known correspondent for leading business magazines in the nation's capital, has been named Washington Correspondent for MODERN CASTINGS. The son of a Chicago foundry owner, Mr. Fingal will keep readers alerted to trends and events in Washington which affect the metalcasting business.

Two sales representative firms have been added to the MODERN CASTINGS sales organization: Don Harway & Co., Los Angeles, for the West; and Pirnie & Brown, Atlanta, for the South and Southwest.

The addition of these two firms brings the number of field sales offices to four, the number of salesmen selling MODERN CASTINGS to fourteen. This makes the present sales staff—each salesman versed in industry—the largest sales organization in the magazine's history.

These four additions are part of a long range development program to improve MODERN CASTINGS' position as the world-wide authority of the metalcasting industry.

Start Study of Seacoal Effects

Investigation of the effects of seacoal has been undertaken by the Molding Materials & Methods Committee of the Sand Division. The Research project was agreed on at a June meeting in Chicago.

The following general procedure was outlined:

Base sand mixture of AFS fineness 60-70 combination lake and bank sand, 15 per cent fire clay. Water to be adsorbed plus 30 per cent free water (4-1/2 to 5 per cent total H_2O). Mull three to four minutes. Seacoal grade C-120. Sand to have the following green properties.

(a) Green compression 8 to 10 psi, dry compression 50-70 psi;

(b) Same sand mixture as above bonded with 7-1/2 to 8 per cent southern bentonite, water 3 to 3-1/2 per cent, mull 3 to 4 minutes. Green sand properties: green compression 13 psi, dry compressive strength 80-85 psi.

It was suggested that this base sand be used for making test castings with 0, 6, and 8 per cent seacoal. Starting with the base sand, castings will be made progressively using the sand but increasing the concentration of seacoal. Surface finish on the castings is to be measured with a profilometer on the drag horizontal surface.

Select Nominating Committee

A nominating committee to select officers and directors for election at the 1961 Annual Business Meeting was named at the August meeting of the Society's Board of Directors.

Six committee members were elected from lists submitted by chapters eligible this year to suggest members. These six with the two immediate past presidents will meet Dec. 12 at AFS Headquarters, Des Plaines, Ill. They will nominate a president, vice-president, and six directors, endeavoring as prescribed by AFS By-Laws . . . To provide equitable and constant regional representation and . . . representative for the several branches of the casting industry."

Members of the committee are:

Past-President Charles E. Nelson, Dow Metal Products Co., Div., Dow Chemical Co., Midland, Mich.

Past-President Lewis H. Durdin, Dixie Bronze Co., Birmingham, Ala.

James A. Barrett, National Malleable & Steel Castings Co., Indianapolis. Representing Region 4—Chapter Group J, Central Indiana Chapter—Malleable and Steel.

Lyle H. Brogley, Farmall Works Div., International Harvester Co., Rock Island, Ill. Representing Region 5—Chapter Group M, Quad City Chapter—Gray Iron.

J. C. Henderson, Omaha Steel Works, Omaha, Neb. Representing Region 6—Chapter Group N, Corn Belt Chapter—Steel.

Edward W. O'Brien, Oklahoma Steel Castings Co. Div., American Steel & Pump Corp., Tulsa, Okla. Representing Region 6—Chapter Group P, Tri State Chapter—Steel.

Roy A. Payne, Sterling Brass Foundry, Inc., Elkhart, Ind. Representing Region 4—Chapter Group I, Michiana Chapter—Brass, Bronze, and Aluminum.

Harry Reitinger, Sr., industrial engineer, Beverly, N.J. Representing Region 1—Chapter Group B—Philadelphia Chapter—Supplies.

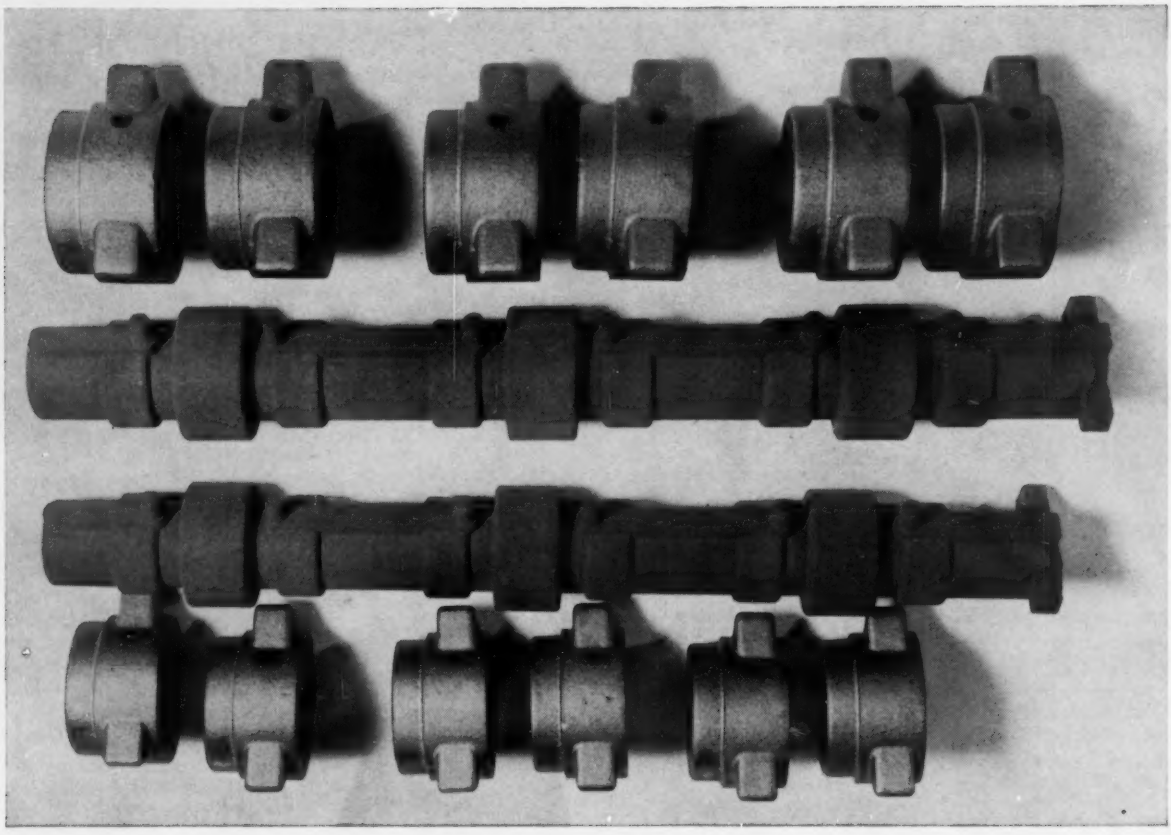
Request Pictures for AFS Defects Handbook

Pictures of typical defects for use in the AFS ANALYSIS OF CASTINGS DEFECTS HANDBOOK are being requested by the Controlled Casting Quality Committee. Glossy photographs, 8x10 inches, are needed of the following:

Broken castings; metal penetration; core raise; open grain structure; fusion; scars, seams, plates; kish; shot metal or cold shots; mass hardness; stickers or rats; and warped castings.

Photographs of these defects on as many metals as possible are needed by the committee. Identification marks will be deleted by retouching the pictures. No identification of company, casting, or pattern will appear in the handbook.

Pictures should be sent to Joseph W. Costello, AFS Controlled Casting Quality Committee, American Hoist & Derrick Co., 63 S. Robert St., St. Paul 7, Minn.



Look what happens to costs when foundry switches to shell cores made with Durez resins

Lavelle Foundries, Anderson, Indiana, casts such things as pump parts, motor housings, venturi fittings and other parts for gas burners. Small, light, a lot of them are needed to account for a ton of iron.

So scrap losses came high. Or did, until shell cores' quality and accuracy helped cut them down to a minimum. More important, with shell cores made from Durez foundry resins it is possible to find and correct the *causes* of poor castings within a few hours, instead of the days or even weeks often required with sand cores.

And costs tumbled even further when gang cores were employed. It took only two cores to make the 12 castings shown in the photo . . . where, before, eight single cores were set per mold.

Finally, with better finishes, closer tolerances, more uniform wall thickness, Lavelle castings save additional sums for customers. Less machining, fewer secondary operations.

OTHER ADVANTAGES

No need for core dryers, less chance for warpage, uniform heat transfer over entire core surface. Less sand to buy, less to handle. Cores are lighter, tougher, can be stacked in stockpiles.

Write for a copy of *Durez Guide to Shell Molding*. It contains all the very latest data on this cost-cutting method.

DUREZ PLASTICS DIVISION
HOOKER CHEMICAL CORPORATION, 8910 WALCK RD., NORTH TONAWANDA, N. Y.

HOOKER CHEMICALS PLASTICS

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CHAPTER NEWS

Regional Vice-Presidents, Directors Receive Chapter Contract Assignments

Assignments for chapter contacts have been made for AFS Regional Vice-Presidents and Directors. Regional Vice-Presidents are AFS representatives in their respective districts.

Among their duties are the conducting of regional administrative meetings and visits with chapters or chapter chairmen. AFS Directors assist them in working with the chapters.

During October, regional meetings will be held in Memphis, Tenn., Cambridge, Mass., and Montreal, Quebec. In November meetings will be held in Saginaw, Mich., Chicago, and Philadelphia.

REGION 1—Vice-President, D. E. Matthieu. Contacts by Matthieu; Chesapeake, Metropolitan, Philadelphia, Piedmont, and Brooklyn Polytechnic Institute. Contacts by Director R. R. Ashley: Connecticut, New England, Massachusetts Institute of Technology, and Wentworth Institute.

REGION 2—Vice-President, A. J. Moore. Contacts by Moore: Eastern Canada and Ontario. Contacts by Director D. E. Webster: Central New York, Southern Tier Section, Eastern New York, Pittsburgh, and Rochester. Contacts by Director W. H. Oliver: Northwestern Pennsylvania, Western New York, and Pennsylvania State University.

REGION 3—Vice-President, D. L. Colwell. Contact by Colwell: Toledo. Contacts by Director R. E. Mittlestead: Canton and Central Ohio. Contacts by Director W. E. Sicha: Northeastern Ohio and Ohio State University.

REGION 4—Vice-President, D. W. Boyd. Contacts by Boyd: Central Michigan and Western Michigan. Contacts by Director R. R. Deas, Jr.: Central Indiana and Cincinnati. Contacts by Director E. C. Jeter: Detroit and University of Michigan. Contacts by Director T. T. Lloyd: Michiana and Michigan State University. Contact by Director C. E. Nelson: Saginaw Valley.

REGION 5—Vice-President, H. M. Patton. Contacts by Patton: Twin City, Central Illinois, Quad City, and University of Illinois. Contacts by Director J. E. Moore: Chicago and Northwestern Illinois & Southern Wisconsin. Contacts by Director N. N. Amrhein: Wisconsin and University of Wisconsin.

REGION 6—Vice-President, Jake Dee. Contacts by Dee: Mexico, Texas, San Antonio Section, Tri-State, and Texas A & M. Contacts by W. C. Jeffery: Birmingham, Mid-South, Tennessee, and University of Alabama. Contacts by Director W. L. Kammerer: Corn Belt, Mo-Kan, St. Louis, Timberline, and Missouri School of Mines & Metallurgy.

REGION 7—Regional Vice-President, J. N. Wessel. Contacts by Wessel: British Columbia, Oregon, Washington, and Oregon State College. Contacts by Director A. E. Falk: Northern California, Southern California, and Utah.

TENNESSEE—Retiring Chapter Chairman Charles E. Seman, Lester B. Knight & Associates, congratulates 1960-61 Chapter Chairman Thomas A. Deakins, Combustion Engineering, Inc., Chattanooga. Seaman will be located for an indefinite period in Europe for the Knight organization.—by John D. Kling

WISCONSIN—Chapter reporter Bob DeBroux, Milwaukee Chaplet & Supply Corp., Milwaukee, and helicopter—furnished by the 1st Wisconsin National Bank—for rides by foundrymen at the Wisconsin picnic.

Central Illinois Chapter

Plans for Program Year

Planning for the program year was made by the chapter board of directors at a July meeting. Considerable emphasis was placed on encouraging apprentices and trainees in the foundry industry.

A report on the work of the Castings Defects Committee of the Sand Division was given by Walter Walz, Caterpillar Tractor Co., a committee member.—by Charles W. Search

CHICAGO—Intrigued by the casting weight guessing contest are J. Florian, H. G. Haines, J. Norris and N. Chambers.—by George Di-Sylvestro

Twin City Chapter

Conducts Annual Picnic

Approximately 100 golfers participated in the annual picnic. Joe Gorske, Progress Foundries, Inc., took low gross honors for the third straight year. Low gross in the guest division was shared by Pete Sundquist and Gordy Groelsch, both of Superior Separator Co.

Foundrymen were defeated in the casting weight guessing contest by Sol Kronick, Harry A. Brown Co., scrap metal company. About 270 members and guests attended the dinner.—by Matt Granlund

CENTRAL ILLINOIS—Ira J. Ladd, Caterpillar Tractor Co., Chapter Secretary-Treasurer; Harold J. Marlatt, Galva Foundry Co., Vice-Chairman; Wally Walz, Caterpillar Tractor Co., Director.

Washington Chapter

Inter-Chapter Tournament

Washington Chapter won the first challenge golf match with the British Columbia Chapter and with it the trophy made and presented by the British Columbia foundrymen. The inter-chapter match will become an annual event.

Chairmen for the event were Charles Smith of the British Columbia Chapter and Thomas O'Brube of the Washington Chapter. Ed Rogers of Washington Iron Works, Seattle, had the low gross score and Jack Peterson, Peterson Pattern Works, Seattle, had the low net score.—by Jim McComb

CANTON—Making certain that the lawn chairs aren't stolen are three American Steel foundrymen: C. Faust, Dave Born, and Mike Folk.—by Charles Stroup

CHICAGO — Chess playing occupied some members of the chapter at its annual picnic held recently. Left to right are: J. Acebo, D. Soderlund, and T. Linabury.—by George DiSylvestro

Oregon Chapter

Belusko Elected Chairman

A. A. Belusko, Electric Steel Foundry Co., was elected chairman at the final meeting of the season. Other officers are: Morgan Rudich, Oregon Steel Foundry Co., vice-chairman; Leonard Fortun, Federated Metals Div., American Smelting & Refining Co., secretary; Ralph Brossart, Columbia Steel Casting Co., treasurer.

Two new directors were elected. They are: Ed Meier, Central Brass & Iron Foundry, and Bill Meyer, Electric Steel Foundry Co.

Following the meeting, members toured the assembly plant of Tektronix, Inc., Beaverton, Ore.—by Bill Walkins

UTAH—Officers and directors met lately to plan the year's activities. Seated are: membership chairman Martin L. Larsen, Utah Foundry Supply; first vice-chairman Byron R. MacKay, Lake Metals Co.; treasurer Fred Hafen and secretary W. William Brown, both of Pacific States Cast Iron Pipe Co.

Also: director Angus Backman, Backman Foundry Co.; past chairman Claud C. Cardall, Pacific States Cast Iron Pipe Co.; chairman Everett Backman, Backman Foundry Co.; and membership chairman William A. Thoresen, Pacific States Cast Iron Pipe Co.—by J. M. Bushnell

St. Louis Chapter

Holds Annual Picnic

Nearly 100 St. Louis foundrymen recently attended the annual picnic. Included on the program were games, refreshments, and dinner.—by W. E. Fecht

Participating in the AFS-T&RI course on cupola melting of iron were instructor T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill.; T&RI Training Supervisor R. E. Betterley; A. B. Helms, Wheland Co., Chattanooga, Tenn.

Also instructor W. W. Levi, consultant, Radford, Va.; T&RI Director S. C. Massari; and T. A. Deakins, Combustion Engineering, Inc., Chattanooga. The course was conducted recently at Chattanooga with the AFS Tennessee Chapter acting as co-sponsor.

PHILADELPHIA — Bethlehem Steel Corp. foursome relaxing at picnic are: Karl H. Kostenbader, Kenneth Bunk, Daniel E. Best, and Harold Downey.—by Leo Houser and E. C. Klank

CHICAGO—A. Denbreejen, center, receives congratulations from G. Smith, Sr., on promotion to superintendent, Gultra Foundry Co., Barrington, Ill. On left is G. Smith, Jr.—by George DiSylvestro

PHILADELPHIA — Participating in annual golf tournament were: Toy Aho., Bethlehem Steel Corp.; Henry Kelly, Dodge Steel Co.; Paul Richter, Gear Div., Fuller Co.; and Robert Kelly, Lansdowne Steel & Iron Co.—by Leo Houser and E. C. Klank

OREGON—Low gross winners in golfing tournament: outgoing chairman Carl Mattson and Jack Stephenson, both of Dependable Pattern Works.—by Bill Walkins.

CENTRAL ILLINOIS—Clarence J. Turner, Caterpillar Tractor Co. Chapter Chairman.—by Charles W. Search

PITTSBURGH—Attendance of approximately 400 members and guests at the annual outing give Chapter Chairman J. D. Wilson and entertainment chairman C. D. Ziel, an opportunity for smiling.—by Walter Napp

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AFS Chapter Meetings

OCTOBER

All-Canadian Regional Foundry Conference . . Oct. 27-28 . . Mt. Royal Hotel, Montreal, Que.

Birmingham District . . Oct. 14 . . Thomas Jefferson Hotel, Birmingham . . J. F. Wallace, Case Institute of Technology, *"Risering of Gray Iron Castings."*

British Columbia . . *See Northwest Regional Foundry Conference.*

Canton District . . Oct. 6 . . Town & Country Restaurant, Canton, Ohio.

Central Illinois . . Oct. 3 . . Vonachen's Junction, Peoria, Ill. . . J. Albanese, Acme Resin Corp., *"Urea Formaldehyde Sands."*

Central Indiana . . Oct. 3 . . Athenaeum Club, Indianapolis . . C. A. Sanders, American Colloid Co., *"New Coring Methods."*

Central Michigan . . Oct. 19 . . Hart Hotel, Battle Creek, Mich.

Central New York . . Oct. 14 . . Drumlins Country Club, Syracuse, N. Y.

Central Ohio . . Oct. 10 . . Seneca Hotel, Columbus, Ohio . . J. A. Gitzen, Delta Oil Products Co., *"Sand Binders & Coatings."*

Chesapeake . . Oct. 28 . . Engineers' Club, Baltimore, Md.

Chicago . . Oct. 3 . . Chicago Bar Association, Chicago . . *Divisional Meeting—Gray Iron, Steel, Sand, Equipment-Engineering.*

Cincinnati District . . Oct. 10 . . Eaton Manor, Hamilton, Ohio.

Connecticut . . Oct. 25 . . Waverly Inn, Cheshire, Conn. . . F. L. Riddell, H. Kramer & Co., *"Control of Quality in the Brass Foundry."*

Corn Belt . . Oct. 21 . . Marchio's Steak House, Omaha, Neb. . . S. S. Phillips, Ohio Ferro Alloys Corp., *"Quality Control in Gray Iron Foundry."*

Detroit . . Oct. 21 . . Wolverine Hotel, Detroit . . Management Night.

Eastern Canada . . Oct. 14 . . Sheraton Mt. Royal Hotel, Montreal, Que. . . T. H. Woods, Canada Iron Foundries, Ltd., *"CO_2 Process in Coremaking."*

Eastern New York . . Oct. 18 . . Panetta's Restaurant, Menands, N.Y.

Metropolitan . . Oct. 3 . . Military Park Hotel, Newark, N. J. . . *Aluminum & Magnesium*: Dr. L. W. Eastwood, Olin Mathieson Chemical Corp.; *Brass & Bronze*: C. R. Knobeloch, R. Lavin & Sons, Inc.; *Iron & Ductile Iron*: H. E. Henderson, Lynchburg Foundry Co.; *Steel & Stainless Steel*: W. A. Kopp, Rsch. & Dev. Div., International Nickel Co. *Round Table Discussion Meeting.*

Mexico . . Oct. 31 . . Ave. Chapultepec 412, Mexico City, Mexico.

Michiana . . Oct. 10 . . Flamm's, St. Joseph, Mich. . . J. S. Schumacher, Hill & Griffith Co., *"Molding Methods vs. Sand Testing."*

Mid-South . . Oct. 14 . . Claridge Hotel, Memphis, Tenn.

Mo-Kan . . Oct. 20 . . Fairfax Airport,

Kansas City, Kans. . . S. S. Phillips, Ohio Ferro Alloys Corp., *"Quality Control in Gray Iron Foundry."*

New England Regional Foundry Conference . . Oct. 14-15 . . Massachusetts Institute of Technology, Cambridge.

Northeastern Ohio . . Oct. 13 . . Manger Hotel, Cleveland . . J. C. Miske, Penton Publishing Co., *"Future Markets for Metalcastings."*

Northern California . . Oct. 17 . . Spenger's Fish Grotto, Berkeley, Calif.

Northern Illinois & Southern Wisconsin . . Oct. 11.

Northwest Regional Foundry Conference . . Oct. 21-22 . . Georgia Hotel, Vancouver, B. C.

Ontario . . *See All-Canadian Regional Conference.*

Oregon . . *See Northwest Regional Foundry Conference.*

Philadelphia . . Oct. 14 . . Engineers' Club, Philadelphia . . W. C. Hale, Dodge Steel Co., *"The Word, Think." Annual Wm. C. Coleman Tribute Meeting.*

Piedmont . . *No Meeting.*

Pittsburgh . . Oct. 17 . . Webster Hall Hotel, Pittsburgh, Pa. . . T. W. Curry, Lynchburg Foundries, *"Operational Controls for Ductile Iron Casting."*

Purdue Metals Casting Conference . . Oct. 27-28 . . Purdue University, Lafayette, Ind.

Quad City . . Oct. 17 . . LeClaire Hotel, Moline, Ill. . . V. Rowell, Archer-Daniels-Midland Co., *"Core Binders."*

Rochester . . Oct. 4 . . Manger Hotel, Rochester, N. Y. . . D. B. Beath, Foundry Services, Inc., *"Exothermic Materials for Ferrous & Non-Ferrous Foundries."*

Saginaw Valley . . Oct. 6 . . Fischer's Hotel, Frankenmuth, Mich. . . J. Waite, A-C Spark Plug Div., GMC, *"Work Simplification."*

St. Louis District . . Oct. 13 . . Edmonds Restaurant, St. Louis . . H. J. Weber, American Foundrymen's Society, *"Air Pollution."*

Southern California . . Oct. 14 . . Furniture Mart, Los Angeles . . J. H. Kimes, Jr., Tennessee Products & Chemical Corp., *"Cupola Practice."*

Tennessee . . Oct. 28 . . Wimberly Inn, Chattanooga, Tenn. . . R. E. Betterley, American Foundrymen's Society, *"Communications."*

Texas . . Oct. 21 . . Menger Hotel, San Antonio, Texas . . Panel: C. R. McGrail and J. Kimes, *"Ductile Iron."*

Timberline . . Oct. 19 . . Denver, Colo. . . S. S. Phillips, Ohio Ferro Alloys Corp., *"Quality Control in Gray Iron Foundry."*

Toledo . . Oct. 6 . . Toledo University, Engineering-Science Building, Toledo, Ohio.

Tri-State . . Oct. 14 . . Wilder's Cafe, Joplin, Mo. . . R. A. Clark, Union Carbide Metals Co., *"Ferro-alloys in the Iron Foundry."*

Twin City . . Oct. 11 . . Jax Cafe, Minneapolis . . G. DiSylvestro, American Colloid Co., *"Veining & Penetration."*

Utah . . Oct. 18 . . Salt Lake City . . S. S. Phillips, Ohio Ferro Alloys Corp., *"Quality Control in Gray Iron Foundry."*

Washington . . See Northwest Regional Foundry Conference.

Western Michigan . . Oct. 3 . . Bill Stern Restaurant, Muskegon, Mich.

Western New York . . Oct. 7 . . Sheraton Hotel, Buffalo, N.Y.

Wisconsin . . Oct. 14 . . Schroeder Hotel, Milwaukee . . *Management Night.*

NOVEMBER

Rochester . . Nov. 1 . . Manger Hotel, Rochester, N. Y. . . A. B. DeRoss, Kaiser Aluminum & Chemical Sales, Inc., *"Aluminum Practices."*

Canton District . . Nov. 3 . . Massillon, Ohio . . *Plant Visitation.*

Michigan Regional Foundry Conference . . Nov. 3-4 . . Bancroft Hotel, Saginaw, Mich.

Piedmont . . Nov. 4 . . Greenville, S. C. . . D. L. LaValle, American Smelting & Refining Co., Federated Metals Div., *"Aluminum Castings Defects & Their Correction."*

Western New York . . Nov. 4 . . Sheraton Hotel, Buffalo, N. Y. . . G. DiSylvestro, American Colloid Co., *"Veining & Penetration."*

Western Michigan . . Nov. 7 . . Fingers Restaurant, Grand Rapids, Mich.

Central Illinois . . Nov. 7 . . American Legion Hall, Peoria, Ill. . . R. H. Jacoby, St. Louis Coke & Foundry Supply Co., *"The Young Engineer in Industry."*

Central Indiana . . Nov. 7 . . Athenaeum Turners, Indianapolis . . L. S. Krueger, Pelton Steel Casting Co., *"Quality Control."*

Metropolitan . . Nov. 7 . . Military Park Hotel, Newark, N. J. . . W. H. Ruten, Polytechnic Institute of Brooklyn, *"Quality Castings Through Training" and Film, "Cast Metals and You."*

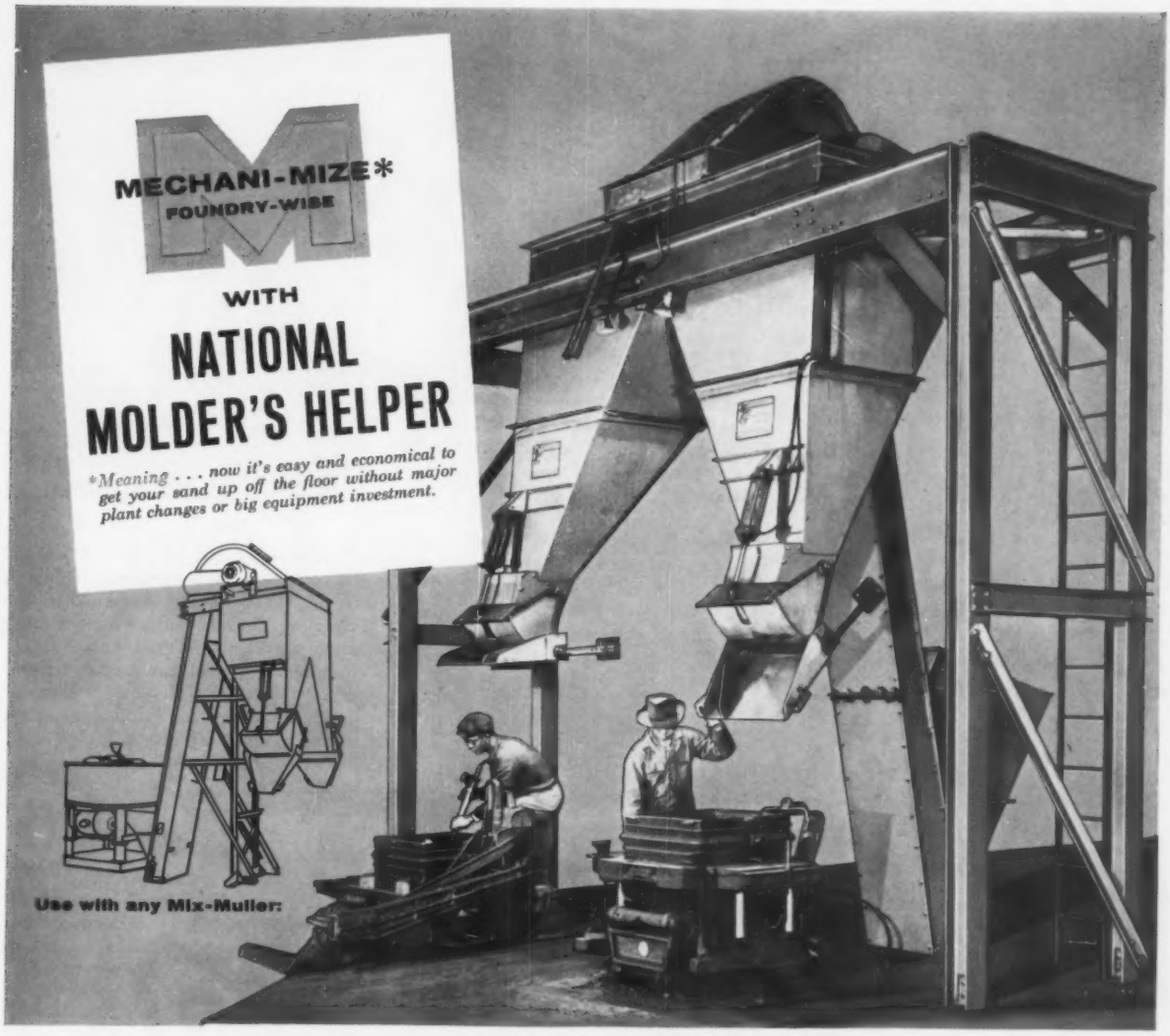
New Books for You . .

Air Pollution Manual . . . Part 1, Evaluation. 194 pages. American Industrial Hygiene Association, 14125 Prevost Ave., Detroit. A technical treatise, written for the layman, explains procedures for evaluating air pollution. Public and community relations are covered and methods of handling complaints presented. The manual is written by authorities in the field. It is a valuable reference work especially for industrial hygienists, air pollution control engineers, plant engineers, management, public health and municipal authorities and others who have an interest in and concern for the air pollution problem. It contains information on: legislation; community relations practice; concentrations of pollutants found in various cities; biological effects of air pollution; air pollution effect on vegetation; farm animals and the community economy; stack sampling; chemical analysis; odor evaluation procedures; radioactive substances; and meteorology.

Accident Facts . . . 96 pages. National Safety Council, 425 N. Michigan Ave., Chicago. 1960. Contains facts and figures on all kinds of accidents—home, traffic, school, public, farm, and work. Several sections are devoted to work accidents and provide a comprehensive background for an industrial safety program. Also contains accident rates by major industry groups and facts on accident trends and off-the-job accidents.

Alloy Manual of the Non-Ferrous Metals . . . Dipl.-Ing. E. Brunhuber. 320 pages. Specialized Press of Schiel & Schon, Inc., Berlin, Germany. 1960. Written in German, the handbook presents the most used German and foreign alloys with respect to their analytical composition. The individual groups of alloys are arranged according to structure under the appropriate systems of alloys, giving a survey of the technical and practical application or use and distribution of the alloys.

It is possible to judge through the appended state diagrams and explanations in simplified form, the technological, physical and structural properties of the alloys, as well as their behavior during the alloying and smelting process, recrystallization, hardening and tempering processes.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Built for foundrymen—to increase molder's production

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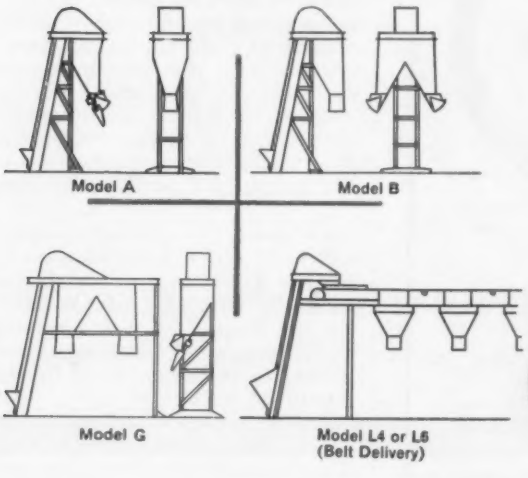

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Molder's Helper is more than a molders hopper with elevator attached. It's an *elevayor* . . . smoother running, faster and more trouble-free than an elevator. It's an *aerator* . . . built-in unit delivers fluffy, free flowing sand to *molders hopper(s)* which are designed and built by foundrymen . . . for fast action, free flowing *foundry* use.

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Circle No. 161, Page 161

Foundry Trade News

Brown Aluminum & Chemical Co. . . . has been formed by Brown Fintube Co., Elyria, Ohio. The firm will specialize in chemical uses of aluminum for the basic steelmaking, stainless steel, and foundry industries. John W. Brown is president of the wholly-owned subsidiary. Other officers are: Edward J. Skiba, executive vice-president; Howard A. Niederst, treasurer; and Frederich W. Dorn, Secretary.

Alu-Bra Foundry, Inc. . . . Bensenville, Ill., has been purchased by Jack Palmer and Emmett Torkelson, both of Elmwood Park, Ill. Palmer, formerly with Howard Foundry Co. and Meskan Foundry Co. is president. Torkelson, formerly with Meskan Foundry Co., is secretary. The firm produces aluminum, brass, and bronze pressure-type sand castings.

American Steel Foundries . . . has announced plans to dispose of its 24 per cent interest in General Steel Castings Corp., Granite City, Ill. The move was announced as a part of the policy to reduce dependence upon the railroad industry. Proceeds will be used to provide part of the capital requirements of the company's 7-1/2 million dollar expansion program which includes construction of a new plant in Bensenville, Ill., and another in Youngstown, Ohio. The Bensenville plant will be a steel wheel facility of the wholly-owned Griffin Wheel Co., located on a 40-acre tract. Ground has been broken and the plant is expected to be completed in 18 months.

Enthone de Mexico . . . Mexico City, has entered into an agreement as exclusive Mexican licensee for Roto-Finish Co. Kalamazoo, Mich., processes and materials. Enthone de Mexico is a subsidiary of American Smelting & Refining Co.

Wisconsin Centrifugal Foundry, Inc. . . . Waukesha, Wis., has acquired Wisconsin Stainless Foundry & Machine Corp., also of Waukesha, which will be operated as the Stainless Div. of the parent company. Officers are M. E. Nevins, president; Paul J. Schneider, vice-president and works manager; Warren Williams, vice-president and technical director; and Kenneth M. Kenney, secretary. Wisconsin Centrifugal has also announced its fourth major expansion in six years. The program includes a two-story office building, 80 per cent larger stainless foundry, 30 per cent larger machine shop, locker rooms, and more efficient shipping and receiving departments. The estimated cost of the 30 per cent expansion is expected to approach $200,000. Total area under roof when the expansion is completed will exceed 72,000 square feet.

Roger Waindle, Investment Casting Institute Vice-President, left, presents "The Whale," the highest award of the Institute to European Investment Casting Association President I. R. Meerkamp van Embden, Phillips, Eindhoven, Holland. Waindle attended the European Investment Casters Association in Belgium where he made the award.

National Research Corp. . . . has announced development of the first large helium-cooled vacuum arc melting furnace for recovery of titanium scrap. The new furnace, also suited for handling other reactive and refractory metals, provides improved operating safety for melting and coating such metals and combines unique features of skull melting by permanent electrode with vacuum melting by consumable electrode. It was developed by N.R.C. under contract for the General Services Administration. Single pours of titanium up to 550 pounds have been demonstrated.

Ferro Corp. . . . Refractories Div., will build a new $300,000 plant in the Los Angeles area to manufacture a line of refractory specialty items for the West Coast now produced by the division's Louthan and Cesco plants in East Liverpool and Crooksville, Ohio.

Crosby Foundry Sales . . . Rocky River, Ohio, has been appointed rep-

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Circle No. 162, Page 161

View of Grey Iron Pallet System. Pallets can be easily moved over rails by hand. Left: Plant Engineer Robert H. Clarke. Right: Scale mounted on fork truck weighs each component of charge.

ENGINEERING APPLICATIONS PAY OFF AT DALTON FOUNDRIES

INCREASED EFFICIENCY

To obtain faster, more efficient, production in the company's gray iron foundry, Robert H. Clarke, Plant Engineer at Dalton Foundries, Inc., Warsaw, Indiana, designed a pallet system. This flexible system allows molders to work two hours before pouring needs to begin. Cooling time can be varied to suit the job and pallets can be easily moved over rails by hand. No bottom boards are used and the handling formerly required to bring them back to the molders has been eliminated. The pallet system provides flexibility for both production and jobbing type work.

BETTER CONTROL

When bond and water are added to sand during mulling, the bond must be thoroughly combinded with water to be effective. Plant Engineer Clarke designed a system to pre-mix water and bond, and pump the mixture into a storage tank where it is stirred continually. From the storage tank, small amounts of the mixture are metered into a tank by a timer. Compressed air then blows this metered amount into the muller at the correct time. This system has resulted in better control of sand, faster mulling cycles, and easier handling of materials.

LOWER COST

At the Dalton Foundries the old wheelbarrow method used to charge the cupola required seven men. Clarke designed a scale which could be mounted on the front of a fork truck to weigh each component of the charge as it was loaded into a drop-bottom tub on the truck. After it is loaded, the fork truck delivers the material to the charging bucket. This simple, and inexpensive engineering change reduced the labor requirement to three men instead of the seven previously required.

You can help create a source of engineering talent for the foundry industry by participating in the FEF program as a contributing member.

Foundry Educational Foundation

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Space contributed by **Modern Castings** as another service to the metal castings industry.

resentative for Nomand Equipment Corp., Milwaukee, for the northern half of Ohio.

Millard Brass & Copper Co. . . . Boston, has been named by American Smelting & Refining Co. as a distributor for its continuous-cast bronze alloys.

Earle C. Call & Associates . . . has been appointed as sales engineering representatives in the San Francisco area for Ransohoff Co., Hamilton, Ohio.

Casting Engineers . . . Chicago producer of investment castings and minicast parts for industrial and commercial applications, has purchased Jelrus Precision Casting Corp. of New York. Jelrus will continue to operate under its own name. John McCormick, formerly Casting Engineers' chief engineer, has been appointed general manager. Sales headquarters will center in Chicago. Casting Engineers is a division of Consolidated Foundries & Mfg. Co., Chicago.

Investment Casting Institute . . . will sponsor an investment casting clinic in Chicago Nov. 1 at the North Park Hotel. The clinic will be a full-day session featuring workshop discussions and special investment casting displays.

Reichhold Chemicals, Inc. . . . White Plains, N. Y., has announced plans for immediate construction of a new phenolic molding compound plant to be located on a 40-acre waterfront property in Ca-teret, N. J.

All-State Engineering Co. . . . Milwaukee, has purchased the industrial crane and hoist operation of Borg-Warner Corp., Chicago. The Borg-Warner operation, which employed approximately 80 people, is being moved to Milwaukee where All-State has built an addition to its present plant to handle the operation.

Hewitt-Robins, Inc. . . . Stamford, Conn., and Union Chain & Mfg. Co., Sandusky, Ohio, have announced that the boards of directors of both companies have approved the acquisition for Hewitt-Robins common stock of the assets of Union Chain, subject to approval of stockholders of Union Chain. Hewitt-Robins plans to operate Union Chain as a division.

Empire Steel Casting Co. . . . Reading, Pa., has appointed Black-Russell-Morris, Newark, N. J., as public relations-publicity counsel. A special technical information program will be conducted.

Elliott Addressing Machine Co. . . . Cambridge, Mass., has sold its wholly owned subsidiary, Whitman Foundry, Whitman, Mass., to Alexander Beck of that city.

American Society for Testing Materials . . . at its annual meeting elected A. Allan Bates, Portland Cement Association, Chicago, to serve a one-year term. Russell W. Seniff, Baltimore & Ohio Railroad, Baltimore, Md., was elected vice-president for a two-year term. Miles N. Clair, Thompson & Lichtner Co., Brookline, Mass., continues as senior vice-president.

New directors serving three-year terms are: Arthur R. Belyea, Consolidated Edison Co., New York; Leslie V. Cooper, Firestone Tire & Rubber Co., Akron, Ohio; Jay C. Harris, Monsanto Chemical Co., Dayton, Ohio; Jerome J. Kanter, Crane Co., Chicago; Robert F. Legget, National Research Council of Canada, Ottawa, Ont.; William R. Willets, Titanium Pigment Co., New York.

Miller & Co. . . . Chicago, has been named as exclusive agent for the Tonawanda Iron Div., American Radiator & Standard Sanitary Corp.

INSPECTION PROBLEMS?
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This comprehensive, elaborately illustrated booklet provides practical information on the use of the famous A. C. M. I. Borescope in various industries, for the inspection of interior areas or surfaces not otherwise visible—together with full data on the types of Borescope available, and on their care and maintenance. Have you received your copy?

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Circle No. 163, Page 161

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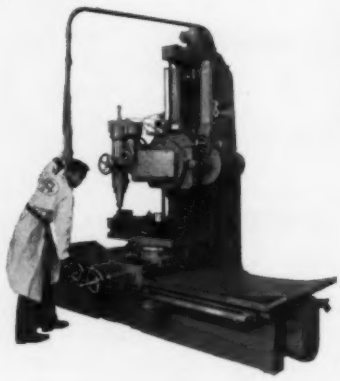

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Circle No. 165, Page 161

Educators' Visit to AFS Headquarters

Paths of Angel M. Velazquez, left, and Roy W. Schroeder, center, cross again two years after picture was taken in Puerto Rico. At that time, Schroeder, professor, department of mechanical engineering, University of Illinois, was in Puerto Rico in an advisory capacity. Velazquez, professor of mechanical engineering at the University of Puerto Rico, recently spent two weeks at the University of Illinois studying its foundry program. Velazquez and Schroeder visited AFS headquarters in August.

Set India Symposium for 1961

A symposium on the light metal industry in India, will be held early in February, 1961 in Jamshedepur, under the auspices of the National Metallurgical Laboratory.

Invitations have been extended to foreign and Indian technologists, metallurgists, and research personnel to submit technical papers, as well as to attend in person.

*John Deere Horicon, Wisconsin

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This Furane combination of Epocast 11B and Hardener 9812 makes a tough, long-wearing surface which withstands the abrasive action of blown sand. Another reason why Furane Epocast tooling plastics are finding widespread acceptance by foundries due to their versatility, economy and ease with which they fulfill difficult requirements.

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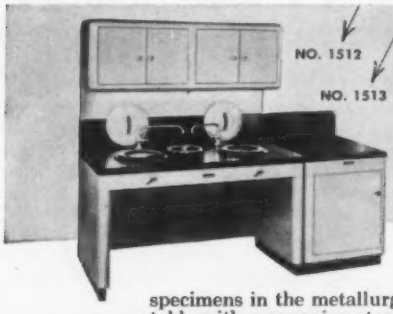

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...with matching storage cabinet...

For maximum efficiency in the production of specimens in the metallurgical laboratory the Buehler cabinet type polishing table with companion storage cabinets represents the latest modern development of this type of equipment.

The convenience of this streamlined polishing equipment saves time and encourages the operator to produce the highest quality of polished sample.

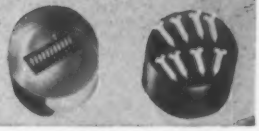
Item No. 1511 is a two-unit polishing table with Formica top approximately 60" long x 27" deep by 30" high to table top. Two 12" swing spouts, drain, 8" diameter wash bowl, plumbing and wiring.

Recommended accessories to complete an efficient set up for maximum convenience are: No. 1512 storage cabinet with recessed light and No. 1513 supporting panel for installation above polishing desk. Or, No. 1514 floor model storage cabinet. Both these cabinets can be used together to advantage in most laboratories.

The Formica top and back on the table and cabinet is installed with a smooth Formica edge that eliminates all metal rims that may form pockets for water and dirt. Covers are held in place on the back by magnetic holders. The large 8" wash bowl is a new feature that enables the operator to use both hands in washing specimens.

All metal construction finished in hammer tone grey makes a very attractive appearance. Prompt delivery can be made on these new items.

The Buehler Line of Specimen Preparation Equipment Includes . . . Cut-Off Machines • Specimen Mount Presses • Power Grinders • Emery Paper Grinders • Hand Grinders • Belt Surfacers • Mechanical and Electro Polishers • Polishing Cloths • Polishing Abrasives



Buehler Ltd. METALLURGICAL APPARATUS
2120 Greenwood Avenue, Evanston, Illinois

Circle No. 166, Page 161

Let's Get Personal . . .

P. H. Stuff

W. F. Tragarz

R. A. Nyquist

M. J. Harvey . . . president, Tyler Pipe & Foundry Co., Tyler, Texas, has been named as the man of the month by the East Texas Chamber of Commerce. The company which has the largest industrial payroll in the area, started with 30 employees.

Walter F. Tragarz . . . has been appointed general foundry superintendent at the Memphis, Tenn., plant of International Harvester and will direct conversion of the plant from a gray iron to nodular iron production. He was formerly general superintendent of the foundry at the McCormick Works in Chicago. While formerly in Memphis he was vice-chairman of the AFS Mid-South Chapter.

Paul H. Stuff . . . has been named as president of Ross-Meehan Foundries, Chattanooga, Tenn. Formerly chief metallurgist, Stuff advanced to executive vice-president in 1958 and became a member of the board.

W. H. Cantwell

J. W. Green

William H. Cantwell . . . vice-president, Eastern Malleable Iron Co., Naugatuck, Conn., now heads new products and diversification for the company's eight divisions. He was formerly managing director of the Wilmington, Dela., division and will retain an office there. **James W. Green,** recently a member of the corporate staff of American Brake Shoe Co., succeeds Cantwell as director of the Wilmington Div.

Robert A. Nyquist . . . is now a metal finishing division sales engineer for Frederic B. Stevens, Inc., Detroit, Mich., and will represent Stevens in western Michigan. He was previously chief process engineer with the Bay City Div., Electric Auto-Lite Co.

James S. Vanick . . . who recently retired after 38 years' service with International Nickel Co., has been awarded the A.S.T.M. award of merit. He was awarded the AFS McFadden Gold Medal in 1956, served as chairman of the technical council, Gray Iron Division and AFS Metropolitan Chapter. His contributions to the foundry industry include the invention and development of the NiHard family of abrasion resistant and NiResist type of corrosion resistant cast irons. In addition he was active in other technical societies include A.I.M.E., A.S.M.E., A.S.M., A.S.T.M., G.I.F.S., American Welding and Ceramic Societies, Corrosion Engineers, British Iron and Steel Institute and Institute of Metals

Paul E. Doucette . . . and **Harry Shwerz** have joined the research and development staff of Hysol Corp., Olean, N. Y. Doucette was formerly employed at Electric Autolite in Toledo, Ohio, and Shwerz was previously associated with U. S. Vitamin Corp.

Richard G. Caulton . . . has been named eastern sales manager, Apex Smelting Co., Chicago, with headquarters in Cleveland. **Donald L. Colwell,** vice-president in charge of laboratories, who has been functioning as sales manager at the Cleveland office during the past two years, will devote full time to research and development work.

Dr. Thomas J. McLeer . . . has been appointed as assistant to the vice-president, Vanadium Corp. of America, New York. He was formerly director of research and development, Cooper Alloy Corp., Hillside, N. J. **William J. Killian,** formerly assistant manager of the Vanadium Corp. Pittsburgh district, has been promoted to Pittsburgh district manager.

Robert E. Garrett . . . has been named president and chief executive officer of United States Pipe & Foundry Co., Birmingham, Ala., succeeding **Claude S. Lawson** who retired. Garrett became

R. E. Garrett

C. S. Lawson

executive vice-president in 1959 and a director and member of the executive committee in 1954.

David G. Cameron . . . has been appointed as a sales engineer for the F. J. Stokes Corp., Press Div., in the New England territory at Portland, Conn. **Roger M. Freberg** has been named as sales engineer for the Vacuum Div. in the West Coast area with offices in Pasadena, Calif. **Clifford R. Smith** is now a sales engineer for the Press Div., working out of the Dayton, Ohio office, covering central and southern Ohio, northern Kentucky, and southern Indiana.

Dr. Joseph F. Libsch . . . a member of the Lehigh University faculty for the past 14 years, has been named head of the department of metallurgical engineering. He succeeds **Dr. Robert D. Stout** who is now dean of the graduate school at Lehigh.

Carmel J. Ruffo . . . has been named superintendent of basic maintenance at Pittsburgh Coke & Chemical Co. He was previously assistant superintendent.

Archibald Jamieson . . . formerly works manager, Canada Iron Foundries, Ltd., Hamilton, Ontario, Can., is now assistant general manager, J. A. Wotherspoon & Son, Ltd., Ancaster, Ontario.

Leo W. Wickson . . . formerly with Universal Engineering Co., Detroit, is now president, Centr-O-Cast & Engineering Co., Detroit.

Lawrence A. Deimen . . . formerly with International Nickel Co. is now metallurgist, Hoskins Mfg. Co., Dearborn, Mich.

John Hood . . . formerly foundry engineer, Atlas Foundry & Mfg. Co., Richmond, Calif., is now foundry manager, Super Mold Corp., Stockton, Calif.

Herbert L. Klopf . . . previously sales service engineer, Thiem Products, Inc., Milwaukee, is now plant manager, Universal Refractories Corp., Greenville, Pa.

R. E. Miller . . . formerly with the National Bearing Div., American Brake Shoe Co., St. Louis, is now with Great Lakes Carbon Corp., St. Louis.

Jay D. Kettering . . . assistant treasurer and comptroller of Miller & Co., Chicago, has been elected to the board of directors. Kettering has been with the company for ten years.

Ernest W. Cummings . . . has been named field engineer for Denison Engineer Div., American Brake Shoe Co., Columbus, Ohio. Cummings will be located in Pittsburgh, Pa.

Bruce C. Knapp . . . has been named chief metallurgist of Alloy Metal Abra-

T. W. Curry

R. J. Dvorak

sive Co., Ann Arbor, Mich. He was formerly with Bridgeport Brass Co.

Thomas W. Curry . . . has been appointed assistant to the president, Lynchburg Foundry Co., Lynchburg, Va. Since August, 1951, he has been director of research.

Richard J. Dvorak . . . is now a sales engineer with WaiMet Alloys Co., Dearborn, Mich. He was previously associated with Chrysler Corp. as a research metallurgical engineer in charge of foundry operations.

Frederick B. Hull . . . has joined the Process Equipment Div., Bethlehem Foundry & Machine Co., Bethlehem, Pa., as a process engineer. He was formerly associated with the U. S. Naval Propellant Plant in Indian Head, Md.

William J. Conway . . . 71, has been honored for 50 years service at the Duncan Foundry & Machine Works, Inc., Alton, Ill. At present he is a machinist in the tool room. He started in 1910 grinding mine car wheels.

Maurice J. Lippincott . . . has been appointed general superintendent of the Florence Pipe Foundry & Machine Co., Florence, N. J. He will have charge of the following departments: sand spun foundry, new foundry, brass foundry, pattern shop, H & V machine shop, machine shop, and forge shop. He was recently elected as a director of the AFS Philadelphia Chapter.

R. C. Conover . . . has been named as general works manager, Refractories Div., H. K. Porter Co. He was previously western district works manager for the Porter Refractories Div. He will supervise the division's 15 refractories plants in Alabama, Ohio, Colorado, Pennsylvania, Missouri, Illinois, Connecticut, and Mississippi.

Drew Graham . . . has been appointed plant superintendent, Fairmount Foundry Co., Philadelphia.

Larry Berger . . . formerly with Swan-Finch Co., is now a sales representative with G. E. Smith Co., Lancaster, Pa.

Frederick E. McMullen . . . has retired after 46 years service with Gleason Works, Rochester, N. Y. During many years of service he was chief gear engineer, was elected to the board of directors in 1950, and as vice-president in charge of engineering in 1951. **Raymond W. Doell**, vice president, has assumed overall administration of engineering activities as engineering manager. **Robert F. Pigage** has been appointed chief engineer of the company's newly organized basic engineering research section. **Harry J. Hart** has been advanced to the post of liaison engineer to serve as coordinator between engineering and sales departments. **John Somerset** is now sales manager for the Gleason Works. **Irving W. Peachey**, is assistant sales manager. **Ralph F. Murphy** is serving as production manager.

R. W. Hodgers, Jr. . . . has been named manager of engineering for the X-Ray Dept., General Electric Co., Milwaukee, succeeding **M. A. Edwards** who has been transferred to Schenectady, N. Y. as manager, advanced product planning, Electronics Component Div.

William F. Boyle . . . has been elected vice-president, General Metals Corp., Los Angeles. He joined General Metals in January of this year having previously been an executive of Baldwin-Lima-Hamilton.

Donald M. Conroy . . . now is sales representative for Acheson Colloids Co., Div. Acheson Industries, Inc., in the

EXECUTIVE REPORT #5

DON'T SAVE PENNIES TO LOSE DOLLARS

the lowest-priced abrasive can be an expensive bargain

Your real concern is the *ultimate cost* of the blast cleaning abrasive you use, not its price per ton. Abrasive quality and performance controls your actual blast cleaning costs. Lower priced abrasives can cost you more, in excessive shot consumption, lower production volume, poor quality of work and excessive machine maintenance. In case after case, high quality Wheelabrator Steel Shot has proven to be the *lowest-cost* abrasive, all factors considered.

You can prove the savings you'll make with Wheelabrator Steel Shot

Your Wheelabrator Abrasive Engineer will demonstrate the performance of Wheelabrator Steel Shot in your own plant. For helpful suggestions to get better cleaning at lower cost, write for our new Handbook of Abrasive Performance. Wheelabrator Corp., 630 S. Byrkit St., Mishawaka, Ind. In Canada, P.O. Box 490, Scarborough, Ontario.

Circle No. 145, Page 161

THE HANDS THAT SHAPE TOMORROW . . . ARE HERE TODAY!

Here skilled hands carefully pilot your patterns through every operation performed on them . . . using the latest methods and finest equipment.

Unvarying high quality is maintained in both metal and wood patterns through careful layout and frequent inspections . . . and it is on such quality that City Pattern Foundry & Machine Co., Inc. has built its reputation.

CITY PATTERN FOUNDRY & MACHINE CO., INC.
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Circle No. 146, Page 161

northern Ohio territory. He was formerly a salesman for the Fabrics & Finishes Div., E. I. du Pont De Nemours & Co.

Edward R. Beardsley . . . has been appointed southern regional vice-president of the Industrial Div., Corn Products Sales Co., and will be located in Atlanta, Ga. He was formerly assistant

E. R. Beardsley

T. A. Bruce

western regional manager and succeeds **Fred C. Hassman. Thomas A. Bruce** is now assistant western regional manager. For the past several years he has been located in New York in administrative positions in sales of the company's industrial products.

Eugene R. Dean . . . has been advanced to assistant general superintendent, Coke & Iron Div. of Pittsburgh Coke & Chemical Co., Pittsburgh, Pa. He had been superintendent of blast furnaces at the Neville Island plant. **William H. Thomas** has been named technical assistant to C. T. Marshall, vice-president of the Coke & Iron Div. He had been general superintendent of the division.

Simon Tice . . . has been appointed foundry manager, Posey Iron Works, Lancaster, Pa. He was formerly with Alan Wood Steel Co., Conshohocken, Pa.

Charles D. Gabor . . . was recently appointed chief engineer of Harbison-Walker Refractories Co., Pittsburgh, Pa. He has been associated with Harbison-Walker since 1941. **Richard P. Snyder** has been made manager of purchasing and engineering. He joined Harbison-Walker in 1933.

Jerry McEvilly . . . has been appointed field representative for the Arcair Co. in the Chicago area. He will headquarter in Milwaukee and will cover nine midwestern states.

obituaries

Fred Fluegge, supervisor of industrial hygiene for 24 years with International Harvester Co., Chicago, died Aug. 24, following a heart attack. He was chairman of the AFS Welding Committee and active on the Safety, Hygiene and Air Pollution Control Steering Committee and the Dust Control and Ventilation Committee. He started as an engineering draftsman with International Harvester, worked in the plant engineering department in the field of industrial hygiene engineering from 1935 to 1944 at Milwaukee, and was then transferred to the Chicago office.

Herman Hetzler, 68, Rochester industrialist and well-known Catholic layman, died of a circulatory ailment Aug. 9. He was owner and president of Hetzler Foundries, Inc., Rochester, N.Y. Hetzler and his father, the late George A. Hetzler, were founders of the firm in 1915. It was originally known as Northwest Aluminum & Brass Foundry.

Dr. H. K. Ihrig, 62, vice-president, research, Allis-Chalmers Mfg. Co., Milwaukee, died Aug. 22, in Milwaukee after a heart attack. He was a holder of 22 patents, among them a process for making steel resistant to corrosion and acids.

Stanley W. Ewing, 66, a sales representative since 1935 for the International Graphite Electrode Corp., a subsidiary of Speer Carbon Co., St. Marys, Pa., died Aug. 5 at his home in suburban Pittsburgh.

For The Asking

Build an idea file for improvement and profit. Circle numbers on literature request card, page 161, for manufacturers' publications.

Complete survey . . . of aluminum welding, brazing and soldering presented in manual. All-State Welding Alloys Co.
Circle No. 1, Page 161

High alloy castings . . . technical publication list offers 46 technical papers, articles, reprints, and data sheets concerning such castings. Alloy Casting Institute.
Circle No. 2, Page 161

Specifications index . . . designed to save time in specifying copper, brass, bronze, nickel silver, and special alloys. American Brass Co.
Circle No. 3, Page 161

Reference chart . . . specifies 55 of the more widely used cast alloys in carbon, low alloy, and stainless groups; also nickel and monel. Lebanon Steel Foundry.
Circle No. 4, Page 161

Copper-base alloys . . . discussed in free reprints of talks presented before American Society for Testing Materials. Brass & Bronze Ingot Institute.
Circle No. 5, Page 161

Hardness conversion . . . chart shows approximate relation between hardness by various testing systems and tensile strength of carbon and alloy steels. Babcock & Wilcox.
Circle No. 6, Page 161

Your invention . . . could be useful for the armed forces; for a 44-p pamphlet spelling out new problems facing the armed forces, use the circle number below. National Inventors Council, U. S. Dept. of Commerce.
Circle No. 7, Page 161

Magnesium alloys . . . advantages in fabrication of electronic components covered in brochure. Dow Metal Products Co.
Circle No. 8, Page 161

Eliminate chilled corners . . . and edges on gray iron castings by inoculating iron in the ladle with graphitizing alloy, according to manufacturer. Request 16-page booklet. Union Carbide Metals Co., Div. Union Carbide Corp.
Circle No. 9, Page 161

CO_2 process . . . for making molds and cores discussed in booklet authored by reported authority in field of foundry facings. Frederic B. Stevens, Inc.
Circle No. 10, Page 161

Refractories . . . handbook, 130 pages, has been completely revised. Includes new products. Walsh Refractories Corp.
Circle No. 11, Page 161

Technical data . . . catalog free. Revised listing of pocket-size books covering every field of engineering. Lefax Publishers.
Circle No. 12, Page 161

Birth of gray iron castings . . . related in technical, colorful, 20 page book. Pittsburgh Coke & Chemical Co.
Circle No. 13, Page 161

Foundry sands . . . described in brochure. Wedron Silica Co.
Circle No. 14, Page 161

Shell molding . . . problems answered in brochure. Answers such questions as, "How to avoid casting fins in shell molding." General Electric Co.
Circle No. 15, Page 161

Wall chart . . . depicting 10 "Do's" and 10 "Don'ts" of grinding wheel safety. Carborundum Co.
Circle No. 16, Page 161

High electrical conductivity . . . copper castings production facilitated through use of deoxidizer-degasifier alloy. Use the circle number below for full details. Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries, Inc.
Circle No. 17, Page 161

Epoxy test kit . . . is yours for the asking. Reported to be ideal for repair or bonding of almost any materials, and resistant to acids, alkalies, grease, and solvents. Fybrglas Industries Div., Schramm Fiberglass Products, Inc.
Circle No. 18, Page 161

Thermal insulation . . . materials guide is designed to enable management and engineers to determine point at which insulation gives the greatest financial return for its cost. National Insulation Mfg. Association.
Circle No. 19, Page 161

Neutral atmosphere . . . to prevent oxidation and de-carburization during annealing, normalizing, hardening, brazing, and sintering is provided by neutralene gas producers. Request bulletin for full information. General Electric Co.
Circle No. 20, Page 161

Electric trucks . . . use in the foundry industry portrayed in brochure which highlights handling of sand and cores, quenching, in-process handling, and operations in storage and shipping. Elwell-Parker Electric Co.
Circle No. 21, Page 161

Combination finishing . . . machine said to be capable of performing 90 per cent of all foundry shop finishing operations. Request 4-page bulletin. Rockwell Mfg. Co.
Circle No. 22, Page 161

Ductile iron . . . castings of consistent physical properties true to shape are achieved because of quality control methods spelled out in this reprint from MODERN CASTINGS. American Foundrymen's Society.
Circle No. 23, Page 161

Magnesium casting alloy . . . provides the highest strength properties for room temperature applications. Bulletin contains data obtained from separately cast test bars as well as from bars cut from castings. Dow Metal Products Co., Dow Chemical Co.
Circle No. 24, Page 161

Pit-type recirculating furnace . . . features positive circulation, wide operating range, and flexibility of application. Four-page bulletin includes, photos, ratings, dimensions, and design features. Sunbeam Equipment Corp.
Circle No. 25, Page 161

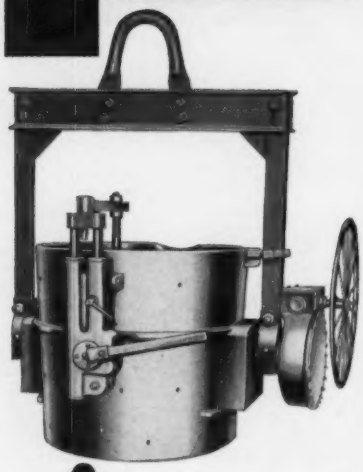
Moisture gage . . . providing direct-reading, relative percentage of sand moisture is detailed in bulletin which also explains moisture and its measurement. Henry Francis Parks Laboratory.
Circle No. 26, Page 161

Maintenance welding . . . data book, 148 pages, includes new application and design data. Also covers general welding techniques and other subjects. Eutectic Welding Alloys Corp.
Circle No. 27, Page 161

Deep trough belt conveyor idlers . . . described in new eight-page book which

safe

slag-free pouring in large volumes



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industrial

EQUIPMENT COMPANY

271 Ohio St., Minster, Ohio

Circle No. 147, Page 161

contains selection data on 60 new 35-degree idlers and 23 new additions to the 45-degree idlers. Link-Belt Co.
Circle No. 28, Page 161

Cut machining . . . in green sand castings with specially prepared carbon additive. Four-page bulletin describes uses and advantages. American Colloid Co.
Circle No. 29, Page 161

Diversified plastics pattern . . . line, including foundry resins, are presented in eight-page catalog giving physical, mechanical, and selection guide. Durez Plastics Div., Hooker Chemical Corp.
Circle No. 30, Paeg 161

Ductile iron . . . reference sheet decribes its use in 32,420-pound printing cylinder. Advance Foundry Co.
Circle No. 31, Page 161

Meehanite nodular . . . brochure provides specifications for five different types with charts for characteristics, mechanical properties, specifications, and applications. Meehanite Metal Corp.
Circle No. 32, Page 161

Bin box . . . selection simplified through 12-page guide which covers design considerations, materials, basic types and variations, optional features, and maintenance. National Wooden Box Association.
Circle No. 33, Page 161

Vibrating feeders . . . synchronize automatically giving high intensity, straight-line motion. Six-page folder explains operations and applications. Link-Belt Co.
Circle No. 34, Page 161

Rotary feeders . . . for controlling sand is subject of bulletin featuring easy-to-read selection procedures as aid in selecting right model. Chain Belt Co.
Circle No. 35, Page 161

Select braided wire rope . . . with pocket card showing revised rated capacities of eight-part braided slings. Reverse side illustrates suggestions for proper sling care and use. American Chain & Cable Co.
Circle No. 36, Page 161

Spectrographic metallurgical control . . . bulletin discusses advantages over conventional wet chemical analysis and outlines benefits to steel casting users. Lebanon Steel Foundry.
Circle No. 37, Page 161

No-baking process . . . for preparation of sand molds and cores in iron and steel castings is detailed in 16-page brochure. Includes performance data, mixing instructions, preparatory steps, types of sands to be used and other necessary technical information. G. E. Smith, Inc.
Circle No. 38, Page 161

Materials handling rentals . . . booklet, 16 pages, features one-page chart enabling owners to itemize and compare operating expenses with cost of renting equipment. Clark Equipment Co.
Circle No. 39, Page 161

Core knock-out . . . and blast cleaning equipment folder on new machine contains diagrams and drawings, photographs of castings before and after core knock-out and cleaning, and case histories. Wheelabrator Corp.
Circle No. 40, Page 161

Control noise . . . for increased efficiency and productivity. Twelve-page booklet illustrates typical examples, flow rates, operating specifications. Allied Witan Co.
Circle No. 41, Page 161

Factory and office equipment . . . booklet, digest size, covers new items added to line. General Industrial Co.
Circle No. 42, Page 161

Aluminum melting . . . reverberatory furnace line for gas, oil, or combination fuel-fired types, features three new models. Complete line described in eight-page brochure. Hevi-Duty Electric Co., Div. Basic Products Corp.
Circle No. 43, Page 161

Conveyor catalog . . . lists new products and techniques for conveyors, casters, wheels, and other materials handling products. Photographs and diagrams illustrate uses. Rapids-Standard Co.
Circle No. 44, Page 161

Cast epoxy core boxes . . . blow 250,000 cores without reworking. Booklet gives details on construction of material which provides cost savings up to 60 per cent. Furane Plastic, Inc.
Circle No. 45, Page 161

Welding training aids . . . lists books on a wide variety of welding subjects, including charts, educational films, cores, and specifications. Hobart Welding School.
Circle No. 46, Page 161

CO_2 brochure . . . eight pages, outlines use of process with foundry molds and cores. Two pages devoted to explanation of how process operates, complete with schematic drawings and photographs. Pure Carbonic Div., Air Reduction Co.
Circle No. 47, Page 161

Exothermic ferrocolumbium . . . folder cites higher columbium recoveries, shorter furnace time, and lower steel production costs as product advantages. Vanadium Corp. of America
Circle No. 48, Page 161

Exothermic products . . . for foundries are discussed in eight-page folder. Included are a complete line of liquidizers, exothermic compounds, and fluxes. Diagrams show product operation. Pittsburgh Metals Purifying Co.
Circle No. 49, Page 161

Silicone rubber . . . publication describes product and application data on complete

LITERATURE REQUEST SERVICE

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family of room temperature vulcanizing compounds. Silicone Products Dept., General Electric Co.

Circle No. 50, Page 161

Heat treating furnaces . . . electrically heated and fuel-fired continuous chain belt conveyor types for heat treatment of small and medium size parts are described in twelve-page bulletin. Electric Furnace Co.

Circle No. 51, Page 161

Stronger cast stainless . . . reprint details new alloy. Case histories and property data in six-page publication shows how alloy is filling need in high strength, highly corrosion resistant applications. Alloy Casting Institute.

Circle No. 52, Page 161

Metalworking lubricant . . . eases extreme stresses to which tools and work are subjected in such operations as tapping, drilling, seat forming, and broaching. Send for sample. Anchor Chemical Co.

Circle No. 53, Page 161

Magnifier booklet . . . aids in making correct selections. Includes tips on correct working distance, determining magnifying power, and field of view facts. Bausch & Lomb, Inc.

Circle No. 54, Page 161

Meehanite castings . . . covered in 32-page booklet listing scope of applications. Also offers table of physical properties. Meehanite Metal Corp.

Circle No. 62, Page 161

Aluminum automotive castings . . . and why they are becoming more competitive is explained in MODERN CASTINGS reprint containing pictures, charts, and graphs. American Foundrymen's Society.

Circle No. 55, Page 161

Modernization . . . mechanization, and maintenance are advanced as necessary steps to meet rising costs and improve quality in MODERN CASTINGS reprint. American Foundrymen's Society.

Circle No. 56, Page 161

Evaluation . . . of mechanical property valuations caused by casting a high purity aluminum alloy part in six different materials is reported in MODERN CASTINGS reprint. American Foundrymen's Society.

Circle No. 57, Page 161

Making castings . . . by a foundry for foundries is described in MODERN CASTINGS reprint. Shop uses precision cast-to-size techniques. American Foundrymen's Society.

Circle No. 61, Page 161

Training Films

. . The following list of motion pictures and film strips will prove useful in educating your personnel to better perform their jobs. Circle the appropriate number on the Literature Request Card.

Principles of foundry work . . . covered relative to making of water-jacket gas-engine cylinder. Covers operations of molding, coremaking, melting, and pouring. Silent, 16 mm, black and white, 45 minutes, $3 rental fee. Purdue University.

Circle No. 58, Page 161

Look to the TS-360 . . . is a new 16-mm film explaining production, operating, and mechanical advantages of company's new 30- cubic yard motor scraper. Color, sound, 15 minutes, free loan. Allis-Chalmers.

Circle No. 59, Page 161

Effect of gating design . . . on casting quality is spelled out in this film, a result of an AFS-sponsored research project investigating flow of molten metal into a mold. Color, sound, 35 minutes, 16 mm, $20 rental plus transportation charges. American Foundrymen's Society.

Circle No. 60, Page 161

Physics of metal cutting . . . film must be booked several months in advance. Black and white, 16 mm, 40 minutes, free loan. Cincinnati Milling Machine Co.

Circle No. 63, Page 161

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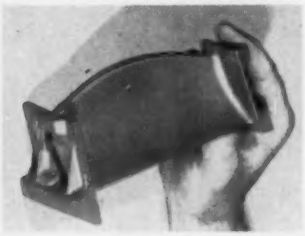
Circle No. 156, Page 161

New Products and Processes

What's new in foundry methods and equipment? Summaries of many are presented below. Circle corresponding number on free postcard, page 161. Mail it to us; we'll do the rest!

Improved Cobalt-Base Superalloy Has Good Foundry Characteristics

An improved cobalt-base high-tungsten superalloy that possesses greatly improved high temperature strength in the 1800 F. range with good ductility and corrosion resistance is now commercially available in both shot and ingot form.



Improved refining techniques and control of alloy elements have increased 1800 F. stress rupture life by 18 per cent and rupture elongation by 160 per cent over previous alloy variations.

The air-melted superalloy has excellent castability and foundry characteristics. It's primary use has been for investment-cast aircraft gas turbine parts such as vanes and blades (shown in picture). Other applications include tools used in hot forming operations, brazing fixtures, and furnace components. WaiMet Alloys Co.

Circle No. 70, Page 161

Ultrasonic Detection Unit Provides Good Resolving Power, Penetration

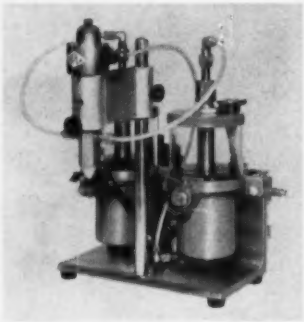
Ultrasonic flaw detection unit, pulse-echo type, reportedly has exceptional low-frequency resolving power and penetration. By sending short pulses of acoustic energy at ultrasonic frequencies into the object, the detector can examine objects from one side only without physical damage.

Defects are indicated by variations in the object's characteristic trace on a cathode ray tube, and approximate depth is determined by a pyramid marker superimposed on the base line. Branson Instruments, Inc.

Circle No. 71, Page 161

Machine Automatically Dispenses Measured, Mixed Epoxy Charges

Automatic dispenser eliminates epoxy waste. Small, self-contained, high-speed machine meters, mixes, and dispenses two component plastic systems.



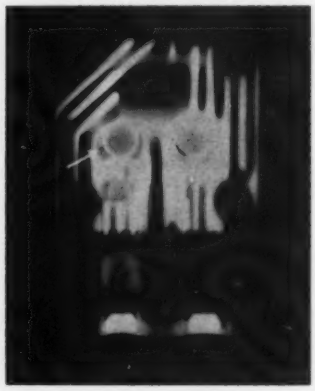
Machine automatically pumps a controlled amount of each component from its reservoirs to the mixing chambers. Unit cycles itself through a controlled motor driven shear and agitation mixing operation. It also dispenses the measured mixed charge with a positive drip-proof cutoff. New Plastic Corp.

Circle No. 72, Page 161

X-Ray Film with Intensifying Screens Gives Better Contrast, Clarity

Intensifying lead screens used with x-ray film reduce overall haziness produced by scattered radiation and produce greater contrast clarity.

Photos show films of a cast cylinder head before and after the use of lead screens. A 0.006-inch lead foil screen was placed in front of the film and behind it a 0.010-inch lead screen. Lead screens are used because less than one per cent of the x-ray energy of primary radiation is absorbed by the film without them.



By clamping the x-ray film between two lead foil screens and the film holder, photographic action on the film is considerably increased. Such intensification results mainly from the absorption by the film of photo electrons emitted by the lead under the action of the radiation. Lead screens also absorb the longer wave-length scatter radiation much more than the primary radiation. Ilford, Inc.

Circle No. 73, Page 161

Resin-Type Sand Binder Eliminates Baking in Core Preparation

Resin-type sand binder which eliminates baking in core preparation, has been used in castings weighing up to 40,000 pounds. Only two additives to the sand are required—the activator and the binder. The core or mold is ready for casting in three

to five hours, depending upon size or complexity. Binder flows freely into core boxes, however, hand ramming is required for producing good core details and sharp edges. Uni-

form strength is developed throughout the core and sand falls free of the casting at shakeout. G. E. Smith, Inc.

Circle No. 74, Page 161

Crane Provides 360 Degree Swing Full Vision in all Positions

Industrial truck crane . . . with 360 degree continuous swing, comes in 12,000 and 20,000 pound capacities. Boom is pivoted well forward to provide working reach the entire length. Visibility is not obstructed in any position of load or crane, in travel or hook work, forward or reverse. Has equal speeds forward and reverse up to 21 mph. Silent Hoist & Crane Co.

Circle No. 75, Page 161

Training Microscope Permits Faster Trainee Development

Training microscope, which permits both instructor and trainee to examine a specimen at the same time, offers several advantages. The trainee sees specific details at the

moment it is described and the new employee learns how to use the instrument quicker and more accurately since the instructor can observe and correct errors immediately. Two basic units can be separated and used independently. Bausch & Lomb, Inc.

Circle No. 76, Page 161

New Centrifugal Machine Produces Lighter, Sounder Castings

Centrifugal casting machine reportedly has advantages over conventional machines by producing lighter castings, higher production with less manpower, and superior quality since there is practically no turbulence in the die during the spinning operation.

Both the die and crucible are spun together and as they are both on a vertical plane, the molten metal starts to climb up the walls of the die, thus creating a vortex. Just before solidification, the die and crucible, still spinning, are turned from the vertical to the horizontal insuring that all metal has entered the die and none remains in the crucible. F. E. (North America) Ltd.

Circle No. 77, Page 161

Unit Cools Shakeout Sand Near Room Temperature as it Enters Muller

New unit quickly cools foundry sand to within room temperature as it enters the muller or storage bin. The elevator-shaped device is charged directly from a shakeout belt. Within the housing, air is passed through the hot sand as it is elevated and aerated by a cleated belt. Cooling is effected by evaporation of moisture. Intensity of cooling is controlled by varying the length of time sand is retained within housing and volume of air exhausted. Three basic models available ranging from 30 to 60 tons per hour. National Engineering Co.

Circle No. 78, Page 161

Spray Coating Gives Corrosion Resistance to Metals, Wood

Spray coating provides a corrosion-resistant surface to metals, wood, and concrete. The homogeneous mixture can be used in many fields where corrosion is a major problem such as on chemical and oil storage tanks, jackets for industrial stack insulation, and industrial ducting of chemical materials. —Owens-Corning Fiberglas Corp.

Circle No. 79, Page 161

Dye Penetrant Locates Defects In on the Spot Applications

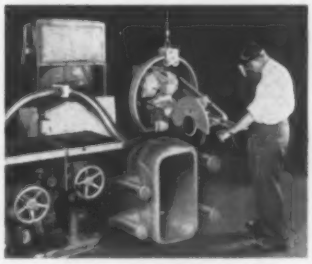
Dye-Penetrant inspection system detects surface flaws in metals and other materials. Compact kit contains both spray and liquid cans for on-

the-spot inspection. Dye penetrant is drawn up by the developer from the defect to make a red stain pattern on a white surface. Picker X-Ray Corp.

Circle No. 80, Page 161

Swing-Frame Cut-Off Machine Takes Six-Inch Cuts in Alloy Steels

Swing-frame cut-off machine permits up to six-inch cuts of any alloy steel as well as conventional foundry metals. Castings can be cut at any



angle by pivoting the head inside the ring, or by rotating the entire head. Unit is shown cutting a side riser from an aluminum casting. Tabor Mfg. Co.

Circle No. 81, Page 161

Solid Rubber Tires Promote Longer Life Under Rugged Conditions

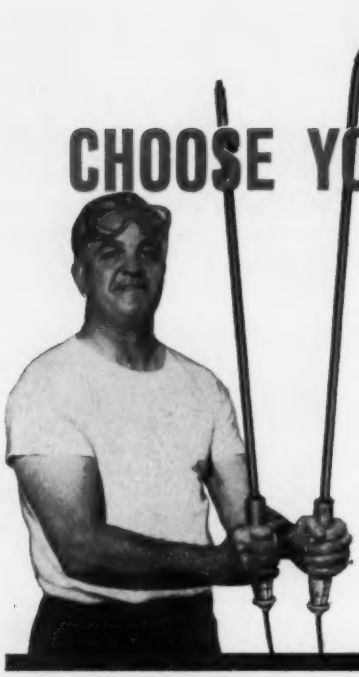
Solid rubber tires made of a series of rubber wedges and specially laminated fabric for resiliency, allow operations over such sharp objects as

glass, scrap metal, brick, stones, and nails. Reportedly the tires also have a greater degree of traction and braking power, even on wet and icy surfaces. Notat Tire Co.

Circle No. 82, Page 161

Castable Ceramic Fiber Withstands Continuous Use up to 2300 F.

Castable ceramic fiber withstands continuous use up to 2300 F., has excellent shock resistance, and does not degrade when exposed to an immediate rise from room temperature to 2100 F. Suggested uses are for furnace and oven wall applications, covers for metallurgical furnaces, boil-



CHOOSE YOUR WEAPON

for WAR against the SCRAP PILE!

Guessing when to pour, or using inaccurate temperature measuring instruments, results in misruns, coldshuts or leaving molds on the floor unpoured. Equip your foundry with dependable Marshall Enclosed-Tip Thermocouples for strong, dense, uniform castings from every melt!

MARSHALL THERMOCOUPLES OFFER THESE ADVANTAGES!

DEEP READING. Takes interior temperature deep within melt . . . tip can be immersed 3 inches or more in depth!

FAST RESULTS. Tip can be stirred to speed reading, giving true temperature in about 20 seconds!

ACCURACY. Pyrometer always indicates steady, accurate reading!

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FLEXIBILITY. Well-balanced thermocouple is convenient to carry and use, simple to operate!

TROUBLE-FREE. Has ruggedly designed parts for long-life reliability. Thermocouple wire can't be contaminated from melt or shortcircuited by slag!

CHOICE OF TYPES. Furnace Type (below, right) . . . lengths up to 10 feet for use with Stationary Pyrometer. Ladle Type (below, left) for use with Portable Pyrometer.

Write today for FREE catalog!

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270 WEST LANE AVE., COLUMBUS 2, OHIO

Circle No. 159, Page 161

er access doors and dampers, and other similar shapes in heat treating ovens. Material is used directly from the shipping container. Carborundum Co.

Circle No. 83, Page 161

Offers Series of Degassing Units Ranging from 300 to 3000 Pounds

Improved surface finish and general soundness, with freedom from voids are possible through vacuum degassing of foundry melts. An additional advantage is the ability of vacuum degassing to generate a carbon boil which minimizes the amount of carbon pickup by the metal, often a major problem when castings are poured by the shell molding process.

A complete series of degassing equipment is available by one manufacturer with capacities ranging from 300 to 3000 pounds. The fixed-base design permits the continued application of reduced power to the furnace during degassing, sufficient to hold the temperature of the melt but not so high as to cause corona discharge. F. J. Stokes Corp.

Circle No. 84, Page 161

Direct Reading Moisture Indicator Acts as Guide for Mixer Operator

Quality control instrument for direct-reading moisture indicator at the mixer, acts as guide for mixer operator where water is added manually.

A moisture sensing probe and a thermocouple thermistor assembly are provided for location in the sand mixer. Both the mixture content and sand temperature are reflected in the movement of separate meters. Control of more than one type of sand mix may be obtained by turning the pointer of the sand factor dial located on the outside of the door panel. Harry W. Dietert Co.

Circle No. 85, Page 161

Flexible Graphite Cloth Useful for Electric Resistance Heating

Graphite cloth features resistance to thermal shock, low thermal expansion, high thermal conductivity, and is not wet by most molten metals. Individual fibers are high purity graphitic carbon with tensile strengths of 50,000 to 100,000 psi.

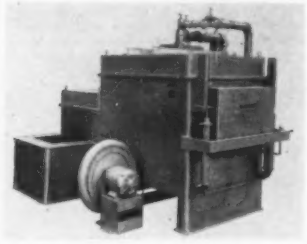
Black body character, electrical conductivity and non-fusible nature of flexible graphite make it useful for electric resistance heating applications such as furnaces and ovens. National Carbon Co., Div., Union Carbide Corp.

Circle No. 86, Page 161

Double Chamber Dry Hearth Furnaces Use Variety of Fuels

New line of double chamber dry hearth aluminum melting and holding furnaces consists of types for aluminum sand casting, die casting, and permanent molding. All three are of single unit construction with individual melting and holding chambers.

Either gas, oil, or combination fuel-fired, the furnaces feature separate firing systems in each chamber for rapid melting in one chamber and correct



holding temperature in the other. Direct firing on a sloping dry hearth makes possible fast melting and immediate run-off of molten metal into the holding bath. Metal quality is achieved as moisture is driven off before the aluminum reaches the holding chamber. Oxides and other foreign materials present in gates, risers and scrap are deposited on the hearth during melting and can be removed with occasional raking. Hevi-Duty Electric Co., Div., Basic Products Corp.

Circle No. 87, Page 161

Two Austenitic Manganese Steels Improve Abrasion Resistance

Two new austenitic manganese steels provide improved abrasion resistance in castings. One is a 12-2 manganese-molybdenum alloy combining toughness and abrasion resistance with a high degree of ductility. The other is a 6-1 manganese-molybdenum alloy with exceptional abrasion resistance but only moderate ductility.

In both, molybdenum makes possible the use of more high carbon contents than is normal in Hadfield manganese steels. Climax Molybdenum Co.

Circle No. 88, Page 161

Magnetic Particle Inspection Uses Specially Developed Solutions

New magnetic particle inspection system uses specially developed solutions which may be sprayed or poured on the surface of a part, allowing the particles to freely migrate in the solution. When the solution sets up, the particles are frozen in place.

Two solutions are available having settting-up times of twenty minutes and eight minutes without the aid of external heat or drying. Patterns may be viewed on the part and washed away or stripped from the part, viewed, and filed for reference. Instruments Div., Budd Co.

Circle No. 89, Page 161

Foundry Achieves 60 Micro-Inch Finish on Gravity Die Castings

Foundrymen have traditionally encountered difficulty getting a micro-smooth surface finish on aluminum gravity die castings. Trouble has arisen because: (1) the entire cavity must be filled without premature solidification of the alloy; (2) adhesion and build-up of deposits between die and casting must be overcome despite high operating temperatures.

Akron Gravity Die Casting Co., Akron, Ohio, is using the Wessel casting process to achieve finishes with little or no surface porosity on the castings. Finishes as low as 40 to 60 micro-inches are reported, and the castings are X-ray perfect with superior density and strength.

As used in the Akron foundry, a Unit-Wessel casting machine is tipped to pour aluminum alloy into the mold cavity. When the cavity is filled, the mold is returned to rest position and the casting removed.

Die cavities are first coated with Aquadag and 'dag' Dispersion No. 193. The former is a dispersion of colloidal graphite in water, and the latter, a dispersion of vermiculite in water. Both are produced by Acheson Colloids Co., Port Huron, Mich., a division of Acheson Industries, Inc.

The casting machine is tipped and die cavities filled by gravity. Previously the cavities were spray lubricated.

The colloidal graphite withstands temperatures above 700 F. without volatizing or causing pockmark due to gas formation. The slick protective graphite film on the die cavity ensures: (1) full metal flow throughout the die, (2) increased die life, (3) easy parting.

The vermiculite-water dispersion is applied to thin sections of the cavity to insulate the alloy from heat loss through mold walls, and to prevent premature solidification. Thus, it helps keep the aluminum fluid and permits rapid flow of the molten metal into thin sections, around curves or various shapes in the die. Shrink porosity and inadequately filled heavy sections are eliminated in the casting.

The coatings are sprayed over the cavities with conventional spray equipment. Both are mixed separately in water with varying dilution ratios. The ratios depend upon the metal being cast, subsequent finishing operations, and configuration of the cavity.

When both dispersions are used, the vermiculite is sprayed first. They are not applied directly to the same area, but limited overspray of the two dispersions does not interfere with the effect.

Circle No. 120, Page 161

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CERAMIC SHELL MOLDS
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Circle No. 171, Page 161

Classified Advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . 35c per word, 30 words minimum, prepaid.
Positions Wanted . . 10c per word, 30 words minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 words.
Display Classified . . Based on per-column width, per inch . . 1-time, $22.00 6-time, $20.00 per insertion; 12-time, $18.00 per insertion; prepaid.

HELP WANTED

CORE ROOM FOREMAN

$650 to $750

Excellent opportunity for advancement in a young growing organization, interested in man with top management potential. Client assumes all expenses. Contact Bill Newell in confidence.

MONARCH PERSONNEL
28 East Jackson Blvd. Chicago 4, Illinois

WANTED

A midwest steel foundry making castings in the range of 50#—1500# desires a man (age 30-40) with foundry experience (must be a journeyman pattern maker) who has good knowledge of heading, gating, and chilling of medium steel castings for a position in staff capacity. Good opportunity for advancement. Write for interview application stating age, experience, and salary expected. **Box J-103, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

GOOD FOUNDRYMEN

when you need **SUPERVISORY** or **TECHNICAL** men why not consult a man with actual foundry experience plus 15 years in finding and placing FOUNDRY PERSONNEL.

Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

For action contact: John Cope
DRAKE PERSONNEL, INC.
29 E. Madison St., Chicago 2, Illinois
Financial 6-8700

FOUNDRY SUPERVISOR—Small twenty-five man aluminum sand foundry looking for experienced foundry man to handle all production duties from procurement of pattern to shipment of castings, permanent mold experience desired. Salary open and some stock available to right man. Reply with resume of experience and references: **Chattanooga Aluminum Foundry, Inc., 2000 Chestnut Street, Chattanooga 8, Tenn.**

MANUFACTURERS REPRESENTATIVES—Presently calling on permanent mold and die-casting shops, ferrous and non-ferrous sand foundries. New group of ceramic facings and related products. Certain volume territories available. Please state experience, current representation and area covered. **Box J-100, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRY SUPERINTENDENT—exceptional opportunity for aggressive leader to assist in the management of a casting foundry located in western New York. Position is in small plant which is part of large corporation. Minimum of ten years foundry experience required. Please send detailed resumes to **Box J-101, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

WANTED-FOUNDRY FOREMAN— for gray and ductile department producing castings in sand and shell. Send detailed resume including salary requirement. **Box I-102, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

PLANT ENGINEERS

Experienced on layout of all types of foundry equipment, material handling and material flows. Send complete details on work history, education and family status. Include recent photograph. All replies confidential. **Box F-140, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

JR. FOUNDRY METALLURGIST

$7,200 to $8,400

Promotable type young man to join rapidly expanding organization that places a great deal of emphasis in engineering proficiency. Client assumes all expenses. Contact Bill Newell in confidence.

MONARCH PERSONNEL
28 East Jackson Blvd. Chicago 4, Illinois

NON-FERROUS FOUNDRY SUPERINTENDENT: A good aggressive minded man (preferably engineer) with proven foundry supervisory experience, required for ultra modern brass small casting captive foundry, producing wide variation repetitive pressure castings. Position backed by staff for quality, methods, budgeting, production control, maintenance, etc. Equipment includes induction melting, automated and standard mechanized production lines. Location, Ontario, Canada. Applicants should write in confidence, enclosing resume, references and salary expected. **Box J-108, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

POSITIONS WANTED

STEEL METALLURGIST—experienced in casting design, gating, risering, alloy, carbon and stainless, arc and induction melting, processing, heat treatments, and quality control. Seeks more challenging position. **Box I-103, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FERROUS, NON-FERROUS FOUNDRYMAN AND METALLURGIST—Has held positions of technical director, district sales manager, foundry engineer, plant metallurgist, and melting superintendent. Worked with sands, shell molding, and gating for high alloy steel and malleable foundry. Presently in investment casting. **Box J-105, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

GRAY IRON FOUNDRYMAN—Twenty years practical experience in acid and basic cupola melting, sand and casting quality control. Age 49. Will relocate mid-west. **Box J-106, MODERIN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRYMAN (West Germany)—well experienced in gray iron and steel foundry operations, light and heavy castings, synthetic, natural and cement-bonded sands, strong in modern foundry practice and quality control, seeks opportunity to work with American firm. Age 39, single, technical college graduate. **Box J-102, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

MANAGER OR SUPERINTENDENT—Foundryman with 20 years experience in jobbing and production foundries—from ounces to 30 tons. Technical background in metallurgy, sand engineering, quality control, testing and control of materials and processes. Resume on request. **Box J-107, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

WANTED TO BUY

BACK VOLUMES — Wanted to buy for cash of foundrymen, **TRANSACTIONS American Foundrymen's Society** and other scientific technical Journals. **Walter J. Johnson, Inc., 111 Fifth Avenue, New York 3, N. Y.**

OVEN wanted—Recirculating, gas-fired, rack type, core or mold baking oven—approximately 6' x 6' x 8', 500,000—750,000 BTU. No junk please. **Iowa Matchplate Company, 207 South Sheridan, Ottumwa, Iowa. Phone: MU 2-0820.**

FOR SALE

ONE MODEL 3 UNIT DRIVE SIMPSON MULLER—with Bucket Loader, Double Discharge Hoppers, Mill Belt, Bucket Elevator, National System Aerator, 14-ft. long Prepared Sand Conveyor, 50 ton Sand Storage Bin. All in good condition. **Address Box H-110, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

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FOUNDRY CONSULTANT — NON-FERROUS Sand casting — permanent mold casting — centrifugal casting — in aluminum — brasses — bronzes — 30% leaded bronze — aircraft quality bearings and castings — ED JENKINS, West Palm Beach, Florida — PHONE: Temple 2-8655.

FREE SERVICE

NEW SERVICE

MODERN CASTINGS announces a new service available to all members of the American Foundrymen's Society. Any member seeking employment in the metalcastings business may place one classified ad of 40 words in the "Positions Wanted" column, FREE OF CHARGE.

Inquiries will be kept confidential if requested. Ads may be repeated in following issues at regular classified rates. Send ads to MODERN CASTINGS, Classified Advertising Dept., Golf and Wolf Rds., Des Plaines, Ill.

Schedule Steel Program

Product and market development regional conferences will be held this fall by the Steel Founders' Society. Locations and dates are: New York, Oct. 21; Chicago, Oct. 21; and Los Angeles, Oct. 31. A conference is tentatively scheduled for Seattle in November.

Diecasters Re-Elect Dollin as President

Gordon C. Curry, Dollin Corp., Irvington, N. J., was re-elected as president of the American Die Casting Institute at its annual meeting held Sept. 14-16 in Chicago's Edgewater Beach hotel.

Also re-elected were Vice-President Walter E. Brown, Kiowa Corp., Marshalltown, Iowa, and Secretary David Laine.

Elected as representatives of the four A.D.C.I. regional groups on the national board of directors were: eastern—W. G. Newton, Jr., Newton-New Haven Co., West Haven, Conn.; central—A. D. Weigolt, Precision Castings Co., Cleveland Div., Precasco Corp., Cleveland; midwest—Fred Klement, West Irving Die Casting Co., Bensenville, Ill.; pacific coast—E. M. Woods, Aluminum Die Casting Co., Los Angeles.

Re-elected as directors at large were: F. W. Burgie, Doehler-Jarvis Div., National Lead Co., Toledo, Ohio, and Alfred Schneier, Jr., Advance Pressure Castings Corp., Denville, N. J. New directors at large are J. C. Bennett, Harvill Corp., Los Angeles, and Walter E. Brown, Kiowa Corp., Marshalltown, Iowa.

STATEMENT OF OWNERSHIP

Statement required by the act of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233) showing the ownership, management and circulation of MODERN CASTINGS, published monthly at Pontiac, Ill., for September 1, 1960. 1—The names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.; Editor, Jack H. Schaum, Golf & Wolf Roads, Des Plaines, Ill.; Managing Director, Harold E. Green, Golf & Wolf Roads, Des Plaines, Ill. 2—The owner is: American Foundrymen's Society, Golf & Wolf Roads, Des Plaines, Ill. Organized not for profit, without stock. Principal officers: President Norman J. Dunbeck, Industrial Minerals Div., International Minerals & Chemical Corp., Skokie, Ill.; Vice-President, Albert L. Hunt, Superior Foundry, Inc., Cleveland; General Manager, Wm. W. Maloney, American Foundrymen's Society, Golf & Wolf Roads, Des Plaines, Ill.; Secretary, Ashley B. Sinnett, American Foundrymen's Society, Golf & Wolf Roads, Des Plaines, Ill.; Treasurer, Edward R. May, American Foundrymen's Society, Golf & Wolf Roads, Des Plaines, Ill. 3—The known bondholders, mortgages, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are none. 4-Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner. Harold E. Green, Managing Director. Sworn to and subscribed before me this 21st day of July, 1960 (seal). E. R. May, notary public. (My commission expires March 14, 1964.)

THE ACME BARGAIN COUNTER

CONVEYORS, OSCILLATING

24" x 40' AJAX; 18" x 24' SIMPLICITY; 24" x 6' SYNTRON; 12" x 20'6" AJAX; 36" x 11' AJAX; 8" x 13' AJAX.

CUTOFF SAWS

DEWALT CUTOFF SAWS: for ferrous or nonferrous metals, cutoff or as sprue cutters. Flush blade adapter takes up to 20" abrasive blade or saw. Power Hoist to arm. Chain & sprocket cross feed for working on heavy cast iron 48" x 60" "T" slot table or off table cutting of large work. Motor swivels horizontal to vertical in yoke.

HEAT TREATING FURNACES

G.E. Elevator Type 1950° Atmosphere Generator 65" x 16' car. Electric, Late; G.E. Elevator Type 2150°—96" x 144" car. Atmosphere Generator Elec., Late; LINDBERG 1250° 48 x 60 Electric; 3—ABBOTT 24" H x 22" Deep x 30" Wide, Gas Fired; HOLDEN #202 1850° Bright Hardening Annealing; 25 KW WESTINGHOUSE 2000°.

INDUCTION MELTING EQUIPMENT

100 KW—AJAX 300# 3000 cycle, 150 h.p. 4 bearings MS set, water cooled, complete controls; 30 KW LEPEL SPARK Gap; 35 KW AJAX Tama Wyatt, 60 cycle induction holding furnaces; 1000# AJAX Space Melting Furnaces.

MOLDING MACHINES, JOLT SQUEEZE PIN LIFT

8—OSBORN 712 PJ 18" x 28" table; 1—CHAMPION JSL10P 18" x 21" table 6" draw; 8—MILWAUKEE 2646 Jolt Squeeze Strip rolloff—rolling molding machines 10" Jolt cylinder; 1800# capacity, 26" Squeeze cylinder; 13" draw, Flask size 25½" to 29" wide, 52" long. FACTORY REBUILT; 2—MILWAUKEE 165, 24" x 30", 8" draw.

JOLT SQUEEZERS

2—CHAMPION, JS10P 18" x 21" table; 2—OSBORN 275PJ; 2—MILWAUKEE 244 Jolt Squeeze car type head; MILWAUKEE 181-7, 24" x 36" table; 113 PJ SPO; 25—124 MILWAUKEE Portable Jolt Sq.; 6—104 MILWAUKEE Portable Jolt Sq.

JOLT ROLLOVER DRAWS

HERMAN 10000# late; HERMAN 3000#; 2—750# HERMAN 20" x 30" table; 1—INTERNATIONAL RJ 20" x 12"; 1—SPO 9032; 3—SPO 506; 1—SPO 506 SP; 2—INTERNATIONAL G; 2—TABOR 30 x 52.

MULLERS and MIXERS

#30 B&P w/skip loader; 1—#3 UD SIMPSON; 1—930 CLEARFIELD; CLEARFIELD #404; 4—#2 SIMPSON OG; #1 SIMPSON OG; 1½ SIMPSON Style "C".

SAND SLINGER & EQUIPMENT

3—19'—2 speed Stationary; 2—14' Turntables; 1—12' Turntable; 1—8' NEWAYGO Plate Feeder; 4—7' B&P Plate Feeders, 35 & 45 Tons.

STRAIGHTENING PRESS HYDRAULIC

225 ton SOUTHWARK; 150 ton HPM; 150 ton FARQUHAR "C" Frame; 100 ton ELMES Hydraulic; 100 ton HANNIFIN Hydraulic; 60 ton LEMCO 4 post; 60 ton FARQUHAR "C" Frame; 25 ton FOX; 25 ton DENNISON.

WHEELABRATORS

27" x 36" AMERICAN w/skip; 48" x 48" AMERICAN w/skip; 6' Table PANGBORN; #1 Rotary Table, AMERICAN; 20" x 27" AMERICAN, w/rubber belt; AMERICAN #2 Tablast 8-28" tables, late; PANGBORN GD1-Airblast Barrel.

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Circle No. 164, Page 161

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Future Meetings and Exhibits

Oct. 10-14 . . Foundry Facings Manufacturers Association, Resort Meeting. Grand Hotel, Point Clear, Ala.

Oct. 10-15 . . National Industrial Sand Association, Semi-annual Meeting. The Greenbrier, White Suphur Springs, W. Va.

Oct. 12 . . Cast Bronze Bearing Institute, Annual Meeting. Grove Park Inn, Asheville, N. C.

Oct. 12-14 . . Gray Iron Founders' Society, Annual Meeting. Netherland-Hilton Hotel, Cincinnati.

Oct. 13-15 . . Non-Ferrous Founders' Society, Annual Meeting. Grove Park Inn, Asheville, N. C.

Oct. 14-15 . . AFS New England Regional Foundry Conference. Massachusetts Institute of Technology, Cambridge, Mass.

Oct. 17-18-19 . . Magnesium Association, Annual Convention. Pick Carter Hotel, Cleveland.

Oct. 17-21 . . American Society for Metals, Annual Meeting and Metal Exposition & Congress. Trade & Convention Center, Philadelphia.

Oct. 17-21 . . National Safety Council, National Safety Congress. Chicago.

Oct. 19-21 . . National Management Association, Annual Meeting. Dinkler Hotel, Atlanta, Ga.

Oct. 20-22 . . Foundry Equipment Manufacturers Association, Annual Meeting. The Greenbrier, White Sulphur Springs, W. Va.

Oct. 21-22 . . AFS Northwest Regional Foundry Conference. Georgia Hotel, Vancouver, B. C.

Oct. 22-25 . . Conveyor Equipment Manufacturers Association, Annual Meeting. The Greenbrier, White Sulphur Springs, W. Va.

Oct. 27-28 . . AFS All Canadian Regional Foundry Conference. Mt. Royal Hotel, Montreal, Que.

Oct. 27-28 . . AFS Purdue Metals Casting Conference. Purdue University, Lafayette, Ind.

Nov. 1-3 . . Investment Casting Institute, Annual Meeting and Design Clinic. Chicago.

Nov. 8-11 . . Society of Die Casting Engineers, National Die Casting Exposition & Congress. Artillery Armory, Detroit.

Nov. 14-16 . . Steel Founders' Society of America, Technical & Operating Conference. Carter Hotel, Cleveland.

Nov. 27-Dec. 2 . . American Society of Mechanical Engineers, Annual Meeting. Statler Hotel, New York.

Nov. 30-Dec. 2 . . Metallurgical Society of AIME, Electric Furnace Conference. Morrison Hotel, Chicago.

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How's Business . . .

Going Up . . .

Miscellaneous types of gray and ductile iron castings shipments in September were up four per cent over August. According to the Gray Iron Founders' Society, Inc., 97 members found business on the increase during September, 98 saw no change, and 61 said business was down from their August volume. Spot checks indicated business good in Indiana, encouraging in Wisconsin, under par in Ohio and Texas. Although backlogs are low in most areas, individual foundries are busy.

American business will spend about $74 billion for plant and equipment in the last half of 1960, according to survey made by Department of Commerce and the Securities and Exchange Commission. This is 10 per cent above the same period last year. Annual expenditures for plant and equipment are expected to run about 20 per cent more than last year, with durable goods producers showing the largest relative gain. Iron and steel producers show the sharpest increase for the year . . . over 60 per cent.

Whereas automobile manufacturers expenditures are scheduled to be about 40 per cent higher than last year and machinery manufacturing groups are expected to spend 1/4 more. In the fourth quarter expenditures are predicted to be about 10 per cent more than for the same period last year. Outlays by railroad and communication companies this year are expected to be about 15 per cent above 1959. Also investment for 1960 is expected to jump to about 12 per cent above the $32½ billion total for 1959.

Going Down . . .

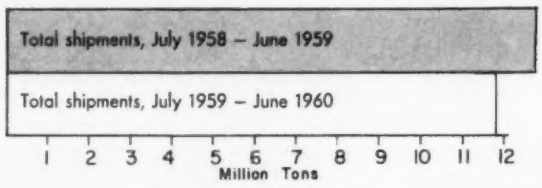
Latest figures indicate that the combined volume of shipments of ingot brass and bronze during July were 14,887 tons. This is 4,738 tons below June shipments and more than 8,000 tons below the March high of 23,232 tons. Compared with shipments of brass and bronze ingots in July 1959, the corresponding month this year is 5,459 tons short. The Council of the Ingot Brass and Bronze Industry believes these figures represent in excess of 95 per cent of the deliveries of the entire industry.

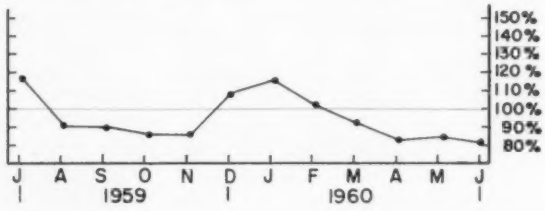
Trends in Metalcastings Shipments

Statistics from Bureau of the Census, U. S. Department of Commerce

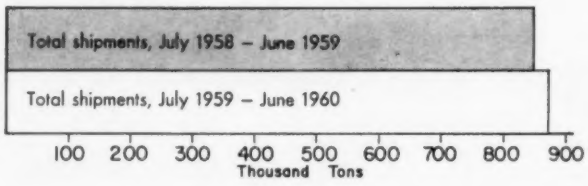
Monthly shipments compared with a year ago.

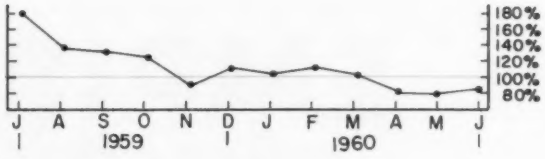
GRAY IRON



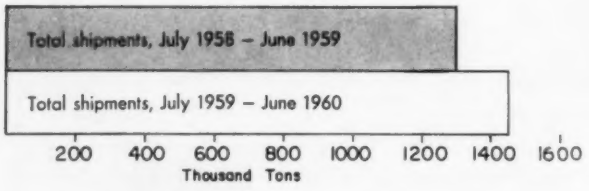


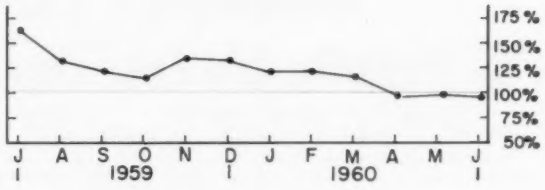
MALLEABLE IRON





STEEL


Total shipments, July 1958 – June 1959
Total shipments, July 1959 – June 1960
200 400 600 800 1000 1200 1400 1600
Thousand Tons



Automakers and auto parts suppliers are about the only industries talking of stepping up steel buying, but this too is tempered by the increased production plans of the compact cars, which require less steel, and also by current heavy stocks of unsold 1960 cars. The last months of 1960 may show only a modest rise in steel production.

Ford Motor Co. is toying with plans to build part of a new compact car overseas for American market. Preliminary planning calls for a four-cylinder car of the Volkswagen size, to be known as the Cardinal. If it proceeds with the car, there is a possibility Ford will use foreign-made parts, and tool up for the car in Europe. Introduction to the U. S. Market would not be before 1962.

With Election Day fast approaching there is a feeling that factories will be running at a faster pace than in early fall. Also there will be a modest pickup in steel and auto production, and consumer prices will level off. There is predicted a general feeling of prosperity with the cost-of-living index declining a point or so, enough to make cheerful headlines. Speculation? Yes, but based, by economists, on three solid arguments: the normal autumn upswing; a two-year rising economy, with a bit of life still left in it; and a government push.

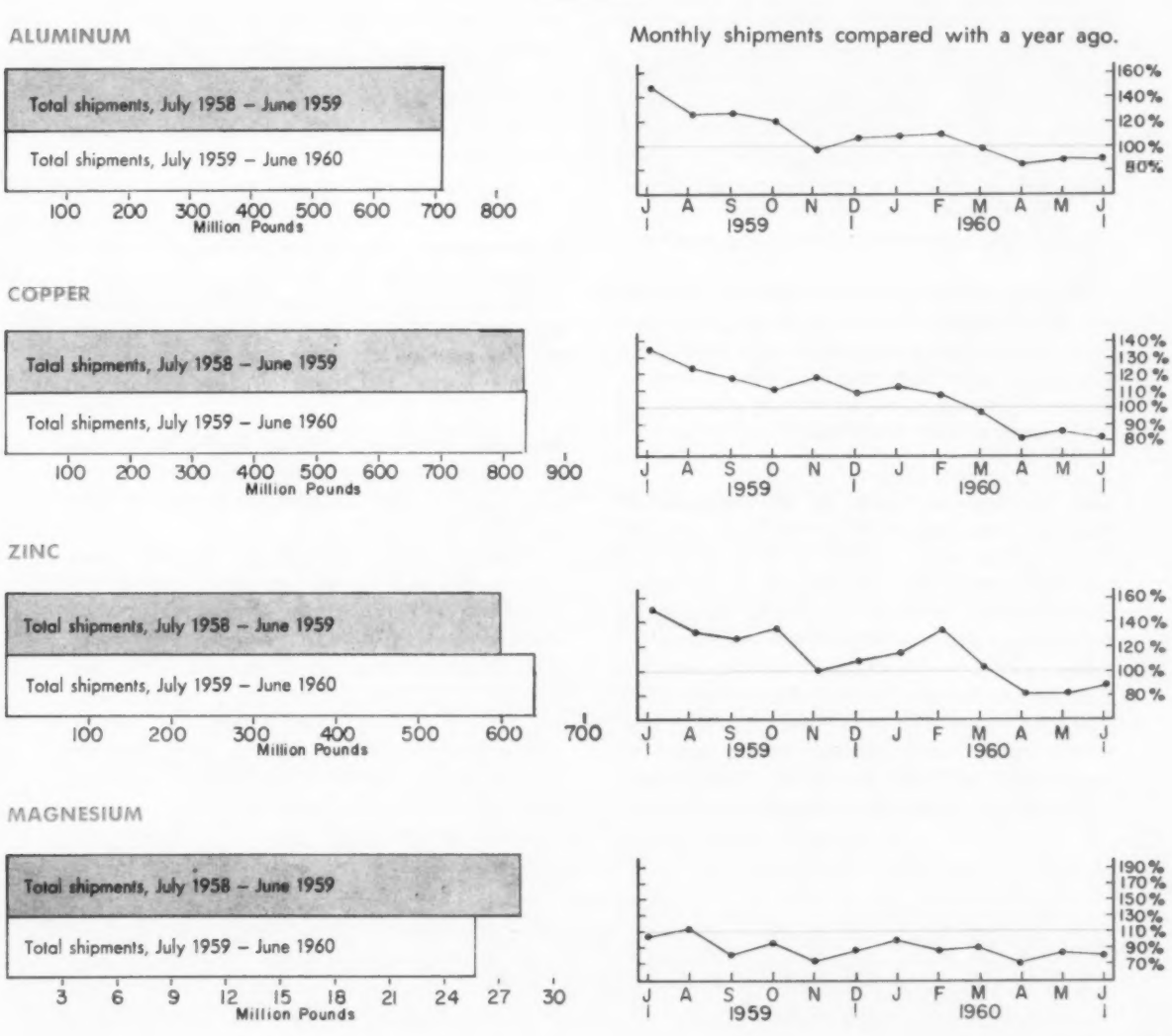
Imported car sales dropped 21,000 units for first half of 1960 compared with same period in 1959. Six-month total equalled 270,713 with Volkswagen's 76,991 still in the lead.

Increased general competition and lower profit margins are major trouble areas in business so far in 1960. The year hasn't developed into the wonderful business year that was anticipated. Generally speaking, however, most of the 87 presidents of the country's largest dollar volume firms, are not discouraged by the present outlook.

They're looking ahead over the next 5 years anticipating a steady growth in the economy. Some 23 per cent are counting on large scale expansion during the next five years.

Metalcasting Shipments

The charts below indicate that, during June, shipments of gray iron castings were down to 84 per cent from 85 per cent in May. Shipments of malleable iron castings were up to 86 per cent compared with 82 per cent in May. Steel, at 95 per cent, was up slightly over May. Shipments of aluminum castings (91 per cent) in June and of zinc at 91 per cent were higher than May, whereas June shipments of both copper castings (82 per cent) and magnesium castings (80 per cent) were slightly below May shipments.



The Editor's Report . . .

The Schmidt Process . . . represents another overseas assist for U. S. casting industry. Developed by Carl Schmidt in Germany, the new process uses a segmented metal mold and sand, plaster, or shell cores. Assembled mold is clamped to tight-fitting lid on induction furnace. About 10 pounds per square inch air pressure is applied to surface of molten aluminum, forcing it up through a feed tube into the mold. The metal in furnace acts as an infinite riser feeding the casting as it solidifies.

The Chevrolet foundry at Massena, N.Y., is using this technique to cast 20-pound aluminum cylinder head castings. The casting machines are automated to a 3-1/2 minute casting cycle. Metal yield and scrap rates are reported lower than experienced in gravity feed permanent mold casting or die casting. The principle of forcing metal up into the mold from the furnace is not necessarily limited to a permanent mold operation. Sand, shell, and plaster molds can be adapted to low-pressure uphill casting and feeding.

One big advantage comes from the fact that the entire supply of metal in furnace acts as a riser so castings are adequately fed. Metal yield is exceptionally high since solidified casting is broken from sprue leaving no riser attached for later removal and remelting.

Are you snowed under by an avalanche of technical magazines every month? . . . are you frustrated by your inability to keep abreast of the accelerated pace of progress in the metal sciences? This dilemma is under systematic attack every day now at the Center for Documentation and Communication Research, Western Reserve University, Cleveland. There are at least 150 different technical magazines now being published in the English language on the subject of metallurgy and metal fabrication. Every important article in these magazines plus hundreds of foreign and fringe interest publications are being abstracted by a crew of 65 specialists at the rate of 50,000 a year. Key information is coded on IBM cards and will soon be recorded on magnetic tape. Magnetic tapes can be fed through a GE-250 electronic-transistorized scanning device which can search 100,000 technical article abstracts an hour. Machine identifies every article containing information on any metallurgical subject specified.

A number of organizations, including American Society for Metals and the National Science Foundation, have pioneered this project. Our industry should be proud to know that the field of metals is the first to be so documented. Research labs and foundrymen desiring a bibliography on any particular subject should avail themselves of this service. It's fast . . . it's accurate . . . the cost is nominal.

Safety record . . . The Haynes Stellite Co., Kokomo, Indiana, holds the best all-time, no-injury record known in the foundry industry. This foundry has operated 7,407,010 continuous man-hours without a disabling injury. Any challenges?

Built and designed by Texas Foundries, Lufkin, Texas—a continuous permanent-mold casting machine which produces 40,000 malleable iron bolts per shift.

A vertical loop of 104 permanent molds move continuously past the pouring station where malleable iron is hand poured. Water spray speeds metal cooling to shrink it away from mold surface. Mold turns upside down and white cast iron bolt falls into chute leading to portable hopper. Acetylene flame coats inner mold surface with carbon before next pouring cycle. Bolts are box annealed, reheated to 1600 F and air quenched for pearlitic structure.

Jack H. Lehman

VOLCLAY BENTONITE

..... NEWSLETTER No. 70 .....

REPORTING NEWS AND DEVELOPMENTS IN THE FOUNDRY USE OF BENTONITE

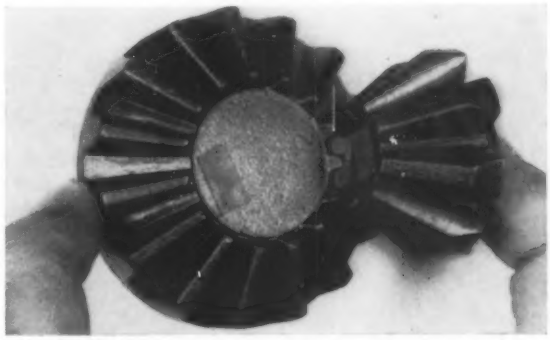
APPLY WHAT YOU NOW KNOW!

Changing times have compelled foundries to do better.

Secrets are disappearing. The new has replaced the old.

The casting industry is demanding improved finishes, closer tolerances and closer dimensional accuracies.

All foundries are striving toward sales appeal and and customer acceptance.



COURTESY OF HAMILTON FOUNDRY INC., HAMILTON, OHIO

This is done by applying what is presently known, rather than investigating unproven processes. The acceptance of castings by producers or Product-design engineers is linked closely with expected casting finish. Many ways may be delegated to reach this goal. One simple method is by use of GREEN SHELL CARB in the following formula:

BY WEIGHT

92%	Silica or Bank sand, AFS Grain Fineness No. 100, or finer
5%	Volclay western bentonite
3%	GREEN SHELL CARB (4% addition may somtimes be required)
2.5%	Temper water added to above mixture

Mix dry two minutes with a slow conventional muller and at least six minutes wet. Mull 90 seconds minimum with a high speed muller.

° ° ° ° °

Naturally bonded sand may be added to the above formula. 10%-20% by weight is the best range. Temper water is increased slightly. This addition may be preferred by non-ferrous foundries.

DO YOU HAVE BULLETIN AF-20, "HOT SANDS"?

AMERICAN COLLOID COMPANY

SKOKIE, ILLINOIS • PRODUCERS OF VOLCLAY AND PANTHER CREEK BENTONITE

GET MINIMUM "PINHOLE POROSITY" IN NODULAR IRON CASTINGS WITH RCI FOUNDREZ 7507

● It's a fact! Nodular iron castings show a marked reduction in gas absorption when your core and shell mold sand is bonded with FOUNDREZ 7507.

FOUNDREZ 7507 is designed specifically for the nodular iron industry and is a supplemental resin recently added to RCI's FOUNDREZ 7500 series of powdered phenolic core and shell mold resins.

This resin is unique in that it contains a minimum amount of gas producing chemicals which can be readily absorbed by iron. In spite of the reduced amount of curing agent, shell molds and cores cure rapidly on a hot pattern or core box.

It also yields the highest tensile strength per unit of resin and therefore has less potential gas in the sand-resin mixture.

FOUNDREZ 7507 has been designed with an intermediate flow rate which makes it suitable for a wide variety of shell mold and core applications. For complete application data on FOUNDREZ, write Reichhold for technical bulletin F-3-Ra.

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